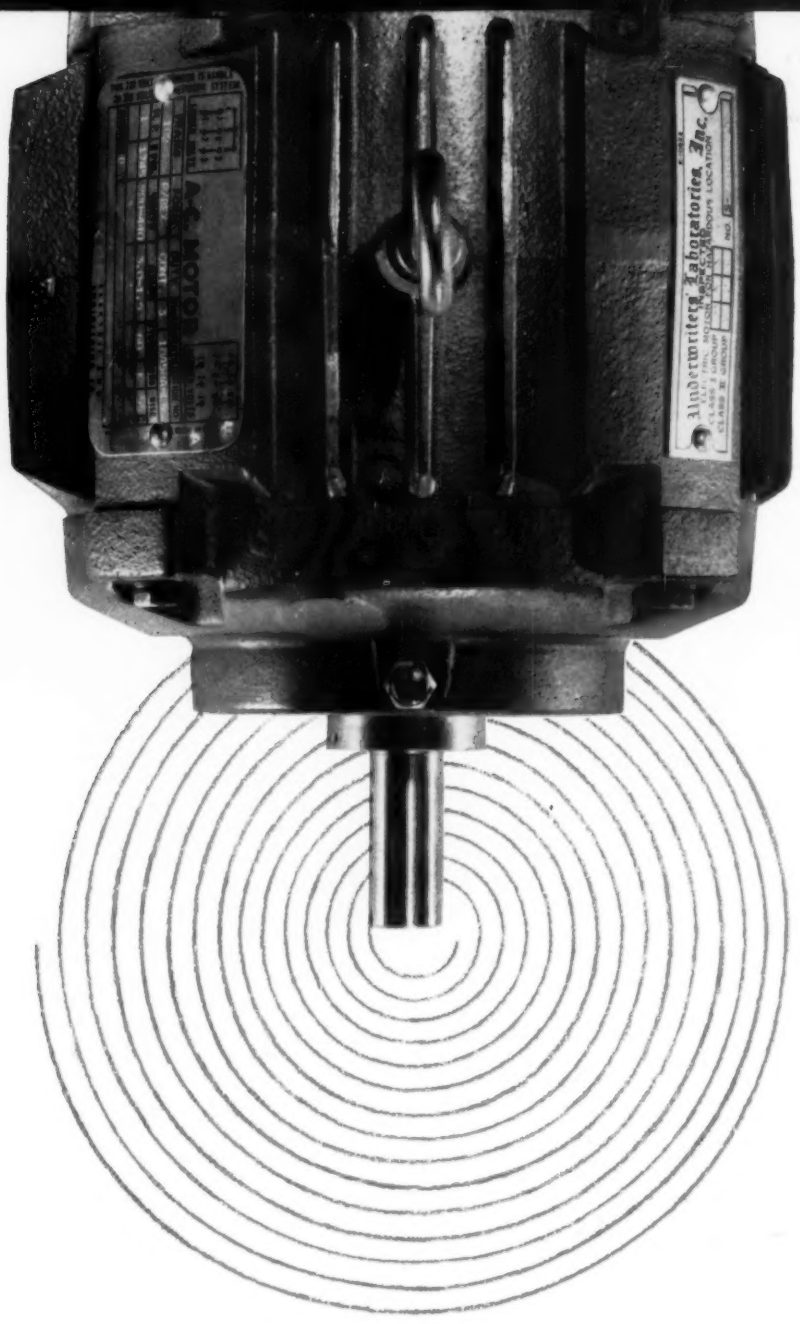
metal progress

April 1961



OPEN UP: for better electrical steels

The Open Coil Process of Gas Alloying permits the control of carbon after the steel has been rolled. Carbon can be removed during the annealing operation. This means that silicon steels of better magnetic properties can be easily and economically produced. By removing carbon from plain carbon steel it becomes an excellent replacement for low silicon grades in many applications. To get all the details on this revolutionary new Open Coil Process of Gas Alloying write for Bulletin OC-960 to *Lee Wilson Engineering Co., Inc., 20005 Lake Rd., Cleveland 16, Ohio.*

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Lee Wilson

Originators and Leading Producers of Open Coil and Single Stack Furnaces

Metal Progress

April 1961 . . . Volume 79, No. 4

COVER: Taken by GLENN BEIER, photographer for the liquid rocket plant of Aerojet-General Corp., Sacramento, Calif., the picture on our front cover shows the first-stage engine thrust chamber of a Titan ICBM being welded prior to furnace brazing in a hydrogen bell furnace at Aerojet.

Technical News in Brief

Die Quenching Hardens Lean Steel Channels . . . Diffusion Coatings Improve High-Temperature Properties . . . High Purity: Key to Refractory Metals . . . Aluminum Improves Free-Machining Stainless Steel . . . Gas Turbine for Trucks Uses High-Alloy Castings . . . New Casting Practice Yields Improved Forging Ingots . . . Progress in Nonmetallic Materials 7

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New Ideas on Aerospace Materials Highlight Western Metal Congress and Exposition 11

Engineering Articles

Selection of Metals for Use at Cryogenic Temperatures, by A. Hurlich and J. F. Watson 65

Since the newer missiles and rockets will be powered by liquid oxygen (boiling point, −297° F.) and liquid hydrogen (boiling point, −423° F.), there is much interest in materials which will remain tough at such low temperatures. This article lists several of the aluminum, titanium, and stainless steel alloys which can be used for low-temperature applications. (Q-general, T24e, T2p, 2-63, 17-57; Al-b, Ti-b, SS)*

Estimating Critical Ranges in Heat Treatment of Steels, by R. A. Grange 73

Formulas are proposed for calculating the upper and lower critical temperatures from the chemical compositions of medium carbon and low-alloy steels. Mean deviations of measured values from calculated values are between 5% and 6%. (N8, 2-60, CN, AY)

Zirconium-Copper Alloy . . . High Strength and Conductivity, by A. E. Moredock and D. K. Fox 75

Copper with 0.15% Zr added combines good electrical conductivity (96% I.A.C.S. after aging) with moderate strengths and hardnesses up to 660° F. Uses: All types of electrical apparatus which need electrical and mechanical properties throughout a range of operating temperatures. (P15g, Q-general, T1, 17-57; Cu-b, Zr)

Brazing Missile and Electronic Components in Dry Hydrogen – II, by H. E. Lewis 94

Purity of the atmosphere and control of temperature will determine the results obtained in brazing in dry hydrogen. Here are some pointers on minimizing contamination and regulating heating and cooling. (K8, T24e, T1)

A New Cast Alloy for Use at 1900° F., by C. G. Bieber and T. E. Kihlgren 97

Laboratory tests indicate that IN-100 – a new nickel-based alloy – has adequate tensile and rupture strength for turbine blades operating up to 1900° F. (Q-general, T7h, 17-57; Ni-b, 5-62)

Trends in Aerospace Manufacturing, by W. D. Nelson, J. A. Scott and R. H. Gassner 106

While new forming and shaping methods, such as chemical milling, electromachining and grinding, subzero and thermal machining (among many others), are used primarily in the aerospace field at present, they could spark a revolution in the manufacture of conventional items. This report outlines many of the fabrication problems which remain to be solved in the fabrication of missiles, rockets and aircraft. (G24, G-18, L-general, K-general, T24, T2p)

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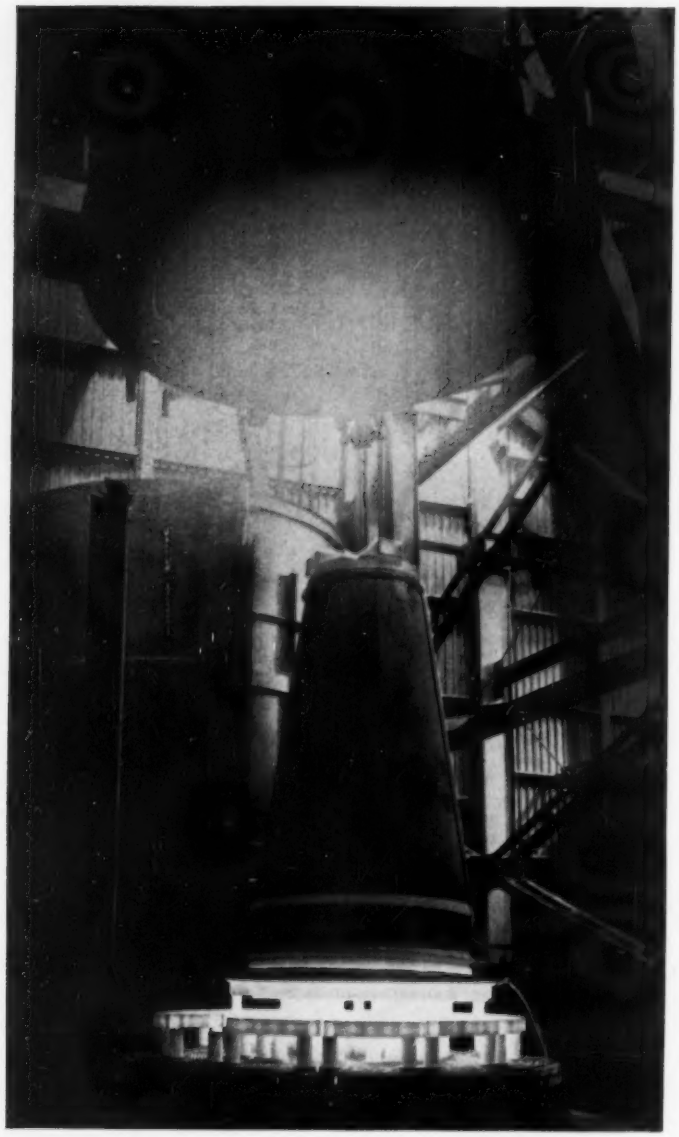
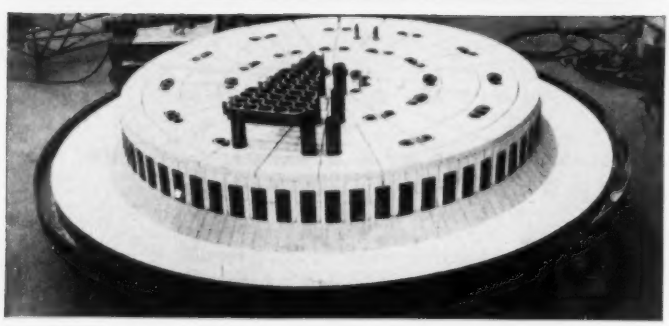
New Alloy Supertherm* proves itself in 2300 degree fahrenheit brazing furnace





Supertherm hearth grid segment during furnace construction.

In a brazing furnace for the thrust chambers of rocket engines at Rocketdyne Division of North American Aviation, Inc., Canoga Park, Cal., a Supertherm furnace hearth grid assembly is operating at a temperature of 2300° F. The grid in a furnace built by the General Electric Company's Industrial Heating Department at Shelbyville, Ind., supports the engine parts during a brazing cycle of from five to eight hours with a maximum temperature of 2300° F. At this extreme temperature and under severe conditions of thermal fatigue created by the brazing cycle, *the Supertherm grid has performed successfully over one year.*

Supertherm is Electro-Alloys' new alloy for the 1800 to 2300 degree fahrenheit range. The composition of Supertherm is 26% chromium, 35% nickel, and is strengthened and stabilized with cobalt and tungsten. For technical information about the composition, physical and high temperature properties of Supertherm, fill out and return the coupon or contact your local Electro-Alloys representative.

*Supertherm is a patented alloy.

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AMERICAN Brake Shoe COMPANY

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Metal Progress

A New Concept in Heating

Principles of the Fluid Bed, by J. D. Stauffer and C. O. Pedersen 78

When a thick layer of small particles of refractory (silica sand, for example) is heated in a container and subjected to a blast of gas from the bottom, it will billow, boil, and flow much like a fluid. This characteristic is the basis for the "fluid-bed" furnace, a new type of heating device which heats parts rapidly and cleanly. (J-general, B15q)

Heat Treating in the Fluid-Bed Furnace, by Charles Bennett and Charles Jung 82

Among other successful applications, the fluid-bed furnace has been used in austenitizing intricate parts of alloy steel and for removing residual stresses from aluminum parts. (J-general, B15q)

Nondestructive Testing for Management — 2

How to Use Magnetic-Particle Methods, by L. B. Strader and D. W. Collins 88

Though useful only for detecting defects at and near the surfaces of ferromagnetic materials (iron, nickel, cobalt and their alloys), this method of nondestructive testing is widely used. There are various types of equipment and techniques with which parts of almost any shape and size can be tested rapidly and accurately. (S13j)

No. 7 in a Series on Better Finishing

I — Phosphating in Cold Solutions, by Robert C. Gibson 100

Improved techniques such as cold phosphating have resulted in expanded applications for phosphate coatings in protecting metal surfaces from corrosion and in preparing them for paints, vinyl and plastisol finishes. (L12, L14b)

II — Phosphating in a Nonaqueous Solution, Staff Report 103

Nonaqueous phosphating solutions based on trichlorethylene combine fast action and low operating costs. They can be used in separate tanks to process parts in batches or in automatic machines which degrease, phosphate and finish parts with paints thinned with trichlorethylene. (L12, L14b)

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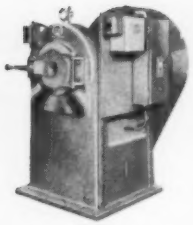
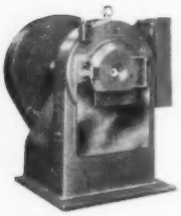
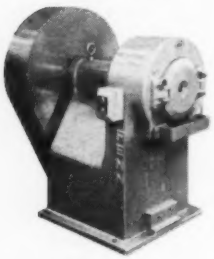
ARE YOU MACHINING WHEN YOU SHOULD BE SWAGING?



Rotary Two-Die

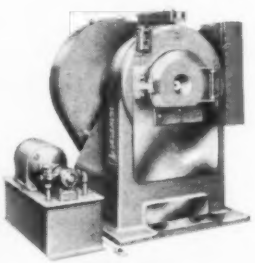


Rotary Four-Die



Long Die

Stationary Die



Hydroformer

Cost conscious manufacturers are finding it extremely profitable to design the components of new products . . . or redesign old ones . . . for production on Fenn swaging machines. What's more, in many cases swaging makes it better. On the *money saving* side, here are important considerations. Low investments in both machines and dies, the absence of chips with resulting savings in both metal and chip handling, lower labor costs because highly skilled operators are not required, and savings in time . . . for swaging is simple in operation, whether manually or mechanically fed. On *making it better*, swaging improves the physical characteristics of the metal, imparts a high finish, maintains continuous accuracy to within $\pm .001''$, and performs many operations possible by no other method. Your nearest Fenn sales engineer can competently advise you on possible application to your product.

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PRESS BREAKS

LAST MONTH WE TOLD YOU ABOUT Marjorie Hyslop's move to devote her full time to managing A.S.M.'s documentation service. Thus, her name no longer graces our editorial masthead (on p. 15 in this issue). You may have also noticed that, although the other editors remain the same, some of the titles have changed. Carl R. Weymueller, who has been with *Metal Progress* for 3½ years, moves up from assistant editor to become associate editor. Carl received his degree in metallurgy from the University of Illinois and worked in Republic Steel's metallurgical laboratory in Chicago for eight years, then at Wyckoff Steel Co. for a few months before coming to *Metal Progress*. Ralph G. Dermott, assistant editor for nearly two years, steps up to the managing editor's post. A Penn State graduate in metallurgy, he has a broad background in nonferrous alloys and in the application of aluminum casting alloys, gained during several years working on aluminum casting alloys at American Brake Shoe Co. and on research and development of wrought copper alloys at Bridgeport Brass Co.

Elizabeth Aldrich moves up to assistant editor, a position which is more in line with the responsibilities she has in looking after the many mechanical details of getting *Metal Progress* out each month. Elizabeth also handles the Personal Mention column, Letters to the Editor department and writes the popular Behind the Bylines feature. In her seventh year with the staff, she came to *Metal Progress* from Oberlin College. She held two summer editorial jobs while pursuing her education, both in New York. Fred L. Siegrist, who remains assistant editor, is the most recent addition to *Metal Progress'* staff. He transferred from the A.S.M. Metals Engineering Institute about a year ago. Another University of Illinois alumnus, his twelve years experience in metallurgy includes research and development work in high-temperature metals (at Wright Aeronautical Corp.), materials for atomic energy applications (at Westinghouse) and aluminum production (for Aluminum Co. of America). Fred is also serving as assistant editor for A.S.M.'s new *Transactions Quarterly*.

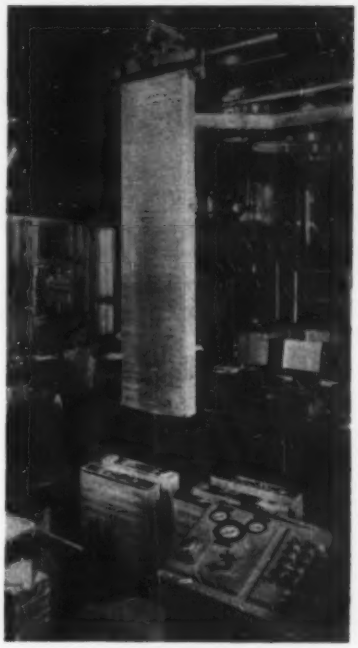
Ernest E. Thum and Allen G. Gray still bear the same titles on the *Metal Progress* masthead, but their positions within the American Society for Metals have changed. Editor-in-Chief Thum has added responsibilities as director of editorial services which includes the coordination of the editorial goals and staff of all the Society's periodicals and reference publications. Editor Gray becomes editor of all periodical publications which includes general editorial supervision of *Metals Review, Transactions Quarterly, Metals Engineering Quarterly* and *Review of Metal Literature* in addition to *Metal Progress*.

We believe the engineering training and broad experience of the editors on the staff of *Metal Progress* will enable us to maintain leadership in publishing technological information to bring more and more profitable reading to you in the years ahead.

THE EDITORS

NEWS FROM

LOMA



After an initial "breaking-in" period, this large LOMA slab casting and sawing installation is now in full production at the aluminum sheet rolling mill of the Quaker State Metals Company, Lancaster, Pa., a division of Howe Sound Company. Capable of producing six 7½ in. x 52 in. x 144 in. aluminum alloy slabs simultaneously, the LOMA semi-continuous casting machine turns out all the ingots required for the processing of sheet, strip and coil. From a quality point of view these continuously cast slabs are greatly superior to those formerly cast in conventional book molds, particularly since one of the methods by which the grain size of the cast material can be controlled is by regulating the casting speed.

For subdividing and trimming the 12 ft. long sheet ingots, Quaker State has also installed a LOMA high-speed circular saw capable of cutting through a 12 in. x 52 in. aluminum alloy section in about one minute. The sawing machine is of the overhead sliding carriage design and employs a 48 in. diameter blade cutting at a speed of 6000 ft. per min. The sawing installation includes a slab charging conveyor, an automatic length stop, a slab discharge conveyor and a chip removal unit. This fully mechanized stock handling equipment combined with the extremely fast feed movement of the saw allows a single operator to run the entire installation at a very high production rate.

LOMA

MACHINE MFG. CO., INC.

114 East 32nd Street

New York 16, N. Y.

Circle 1569 on Page 48-B

CONVENTIONAL COPPER

Severe heat checking after 4679 hot runs

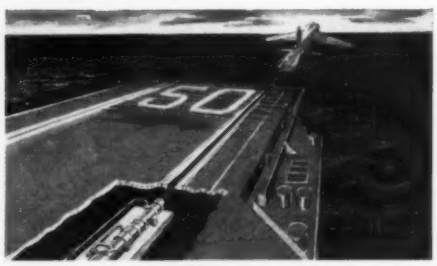
AMZIRC

No appreciable thermal effects after 6941 hot runs

AMZIRC® ZIRCONIUM-COPPER ALLOY

withstands more than 6900 hot runs of catapult powerplant at 3500 F

A critical factor in the success of the Internal Combustion Catapult Powerplant developed by Thiokol's Reaction Motors Division is reliability of the orifice plate that directs a 3500F igniter flame into the combustion chamber. When plates of conventional copper failed, Reaction Motors Division turned to AMZIRC, AMCO's new Zirconium-Copper Alloy that combines high conductivity with remarkable resistance to thermal impact. They had their answer!



Reaction Motors (Division of Thiokol Chemical Corp.) ICCP can launch a 100,000 lb. aircraft at an end speed of 125 knots in 2.25 seconds.

DESIGN REQUIREMENTS:

5000 cycles of 7 sec running at 3500F, 7 sec water cooling, 16 sec rest

	Copper	AMZIRC
Specifications	per Fed Spec QQ-C-576, temper soft anneal	0.1% Zr solution treated, cold-worked, aged
Total runs	4679 cycles	6941 cycles
Condition on removal	deep heat checking, orifice enlarged from 0.562" to 0.572"	no heat checking, orifice enlarged from 0.562" to 0.572"

For complete technical data and metallurgical assistance on AMZIRC contact AMCO's Technical Service Section.

AMCO a division of American Metal Climax, Inc.

1270 Avenue of the Americas, Rockefeller Center, New York 20, N. Y.

AMZIRC is also known as N-4 Alloy

Circle 1570 on Page 48-E

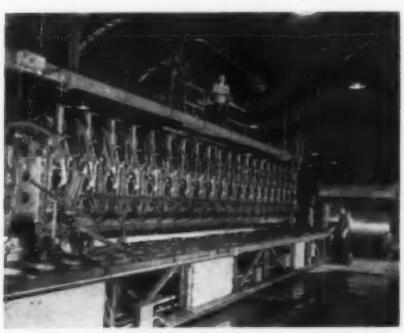
Die Quenching Hardens Lean-Steel Channels

During recent years, the steel industry has emphasized the economy of designing to the full potential of steel thus achieving savings in weight and costs. This fits in fine with thinking in the transportation industry because operators of trucks and trailers have been demanding weight reduction and more ruggedness in their equipment. The object: bigger payloads.

Recently, engineers at A. O. Smith Corp., Milwaukee, Wis., came up with one answer to this need. They have designed die quenching equipment (see photo) which permits side rails up to 40 ft. long for trucks and trailers to be made from a lean steel. Quenching is severe enough to produce a martensitic structure throughout the rail. With tempering, the steel, a modified A.I.S.I. 1027 grade (0.22 to 0.28 C, 1.00 to 1.35 Mn), exhibits properties that are more than adequate for the job. Yield strength averages about 117,000 psi., tensile strength 127,500 psi. and elongation 17%. Test specimens have showed a 15 ft-lb. transition temperature of −85 to −90° F. In addition, the steel can be arc welded readily without great danger of underbead cracking. Low-hydrogen rods such as A.W.S. 11018 are recommended.

Key factor in the efficiency of the die quenching equipment is its ability to circulate an abundant supply of water around the hot rail. In operation, the U-shaped channel, austenitized at 1650° F., is transferred quickly to the quenching machine. A punch and die close around it, exerting enough pressure for straightening. Next, water is pumped rapidly through the waffle-like faces of the punch and die so that it contacts all sides of the rail. Tempering is done in a separate furnace.

Besides being a unique piece of equipment, the die quenching machine offers economic advantages. Previously, high-strength side rails were made of S.A.E. 8620 and often warped when quenched in oil. After being tempered, they needed laborious straightening, an expensive operation which the new equipment eliminates.



DIE QUENCHING MACHINERY
It Quenches and Straightens U-Channels Made From a Modified A.I.S.I. 1027

Diffusion Coatings Improve High-Temperature Properties

New diffusion coatings applied to heat-resistant alloys are now being tested on jet engine blades, head shields which protect aircraft skins, exhaust valves, heat treating trays, glassmaking equipment and industrial waste burners. Based on recent tests at Haynes Stellite Co., Div. of Union Carbide Corp. in Kokomo, Ind., the coatings improve resistance to oxidation, flame erosion, fatigue and thermal shock.

The company has developed two coatings, one recommended for nickel-base alloys, the other for cobalt and iron-base alloys. Both are applied by heating the

parts in a sealed retort with the necessary carrier and pack compounds.

In Charpy impact and stress-rupture tests, the new coatings have enough ductility so that they do not spall from the base metal. The most adherent of the two did not crack even when tested at room temperature.

To check resistance to thermal shock and flame erosion, wedge-shaped specimens were heated for 7 sec. to about 1950° F. in an oxyacetylene flame and then cooled for another 7 sec. in a blast of air. Tests made on coated and uncoated specimens (Haynes alloy No. 152 and 713 C) revealed that the coatings prevent cracks and erosion. Four uncoated specimens of alloy No. 152, for example, cracked in 50 to 200 heating and cooling cycles and showed considerable erosion. Their coated counterparts, however, sustained no damage even after 2000 cycles. Additional tests involving continuous exposure to an oxyacetylene flame (2050° F.) for 3-hr. periods were made to determine weight losses. Under these severe conditions, uncoated specimens of the same alloy lost about 42.8 mg. compared with a gain of 4.7 mg., attributed to the formation of a protective oxide film, experienced by the coated test pieces.

High Purity: Key to Refractory Metals

To a great extent future use of refractory metals will depend on producing them in extremely pure form to obtain the best possible physical and mechanical properties. Excellent ductility, minimum strain hardening, high corrosion resistance and good stability relative to aging are but a few of the improved properties not always associated with refractory metals but which can be obtained by electron-beam floating-zone refining. Single crystals 18 in. long of such metals as tungsten, molybdenum, tantalum and columbium, having interstitial impurity contents in the range of 10 ppm., have been grown using electron-beam apparatus. Sheldon Weinig, president of Materials Research Corp., Yonkers, N.Y., states that these metals in no way exhaust the list of materials that can be processed in this manner. Uranium compounds and ceramic materials have already been produced.

Refractory metals which are commercially available generally must be fabricated at elevated temperatures, but crystals prepared by electron-beam floating-zone techniques are so pure that they may be plastically deformed with ease at room temperature. For example, tungsten may be cold rolled, and molybdenum has been deformed 87% in rolling at room temperature and displays considerable ductility at the temperature of liquid nitrogen

ELECTRON BEAM AT 6000° F.
Floating-Zone Refining by Electron Beam Produces High-Purity Refractory Metals

(−320° F.). Tantalum has been cold swaged 80% into wire that is ductile and displays little tendency to strain harden. Although it is not possible to predict that all refractory metals will be fabricated in the cold state regardless of size or treatment, it is possible to envision numerous small parts being manufactured without heat treatment during processing. An immediate application is in miniature electronic vacuum tubes which require superpure refractory metals for tiny precision parts.

Just as low impurity content results in high ductility, it also results in improved corrosion resistance. It may be possible to deposit (using electron-beam techniques) ultrahigh-purity refractory metals on bulk material to obtain a corrosion-resistant skin. Thus, very pure tungsten could be deposited on a part made of commercial tungsten.

Aluminum Improves Free-Machining Stainless Steel

Although the machinability of austenitic stainless steel is improved by additions of sulphur, 0.25% of it seriously lowers the corrosion resistance and formability of Type 303, the standard free-machining grade. But metallurgists at Universal-Cyclops Steel Corp., Bridgeville, Pa., have found that decreasing the sulphur content to 0.13% and adding aluminum (0.70%) eliminates the adverse side effects and produces a marked improvement in machining characteristics. Corrosion resistance of the alloy,

Technical

NEWS

In Brief

Uniloy 303 MA, is 25 times greater than Type 303 and approaches that of Type 304. Producers of fasteners, valves, and fittings who have worked with the alloy for the past year report increases of up to 50% in output of machined parts, longer tool life, and improved surface finish. Increased formability permits thread-rolling operations (threads must be cut on Type 303 parts).

The improved performance of the alloy—resulting from a reduction in nonmetallic inclusions—means that Uniloy 303 MA can advantageously replace Type 303, and can be specified for many applications where Type 302 and 304 are now used.

Gas Turbine for Trucks Uses High-Alloy Castings

The potential of the gas turbine engine (it can produce more power per pound and can burn many kinds of fuel) as a competitor to the reciprocating engine for automobiles and trucks has not gone unnoticed. But the problem of finding materials which will provide economical and reliable performance has been a major hurdle not yet passed.

Recently a gas turbine engine built by Allison Div. of General Motors Corp., Indianapolis, Ind., went into service in a truck used to haul 32-ton loads of nickel ore. To cope with high stresses and operating temperatures, Allison engineers have used castings made of S.A.E. 60347 alloy (Alloy Casting Institute designation CF-8 C) for six key components in the hottest sections of the engine.

Containing up to 1% Cb, 18 to 21% Cr and 9 to 12% Ni, CF-8 C alloy is intended primarily for areas where corrosion and long exposure to high temperatures are encountered. In the solution-treated condition, it is essentially austenitic, and when it is heated between 800 to 1600° F., columbium carbides precipitate rather than chromium carbides. As a result, there are no chromium-depleted areas and intergranular corrosion is prevented. Also, at 1200° F. the limiting creep stress (at a creep rate of 0.0001% per hr.) is about 18,000 psi., well above the maximum requirement.

An example of the application of CF-8 C is in the three castings that make up the bulkhead of the gas turbine engine. This part separates and seals the gasifier section from the power turbine section and operates at 1300° F. It must also resist a pressure differential of 2 atmospheres which combines with the high service temperature and structural warpage to set up a severe fatigue condition. The assembly of three CF-8 C castings replaces a complex structure of sheet metal (400 series stainless steel) which was welded together.

Parts made of the alloy are also used near the hot combustion gases, as a liner in the gasifier section and as a nozzle support.

New Casting Practice Yields Improved Forging Ingots

As a result of a new molding technique which improves the surfaces of steel ingots, steelmakers have been able to cut ingot-to-billet costs by one third. The technique, which is now being used in Torrance, Calif., by National Supply Div. of Armco Steel Corp., also results in longer ingot mold life, permits refractory-type inclusions to be removed from the metal while it is being poured, and allows higher pouring temperatures.

Known as fluid-mold casting, the process was described at a recent meeting of the A.I.M.E.'s Electric Furnace Committee by J. T. Evans, superintendent of the plant's melting department. It was devised primarily for producing clean steels for forgings, and owes its effectiveness to a special slag introduced in the liquid state at the bottom of the ingot mold. As the metal rises in the mold, the slag coats the ingot and fills any cavities in the mold wall, forming a smooth film around the ingot.

National Supply melts the slag in a 3-ton direct-arc furnace. A graphite ramming mix is employed for lining the tapping spout and the bottom of the furnace. Since the slag will not conduct electricity when cold, melt-down must be started with a graphite tee. When liquid, the slag becomes conductive so that once a pool is formed the tee is removed and the electrodes are immersed. The slag is then heated to 3200° F. and transferred to

NEW PROCESS IMPROVES FORGING INGOTS
Slag Film Covers Deep Fire Checks During Teeming to Produce Smooth Ingots

Technical
NEWS
In Brief

the pouring pit. About 50 lb. of it is poured into the mold for each ton of gross ingot weight, and the steel is teemed immediately.

Progress in Nonmetallic Materials

Nylon filled with molybdenum disulphide has been made into thrust washers used on Sendzimir rolling mills. The nonmetallic material replaces bronze washers in two mills which roll specialty steels at Wallingford Steel Co., Wallingford, Conn. Under compression loads, it was found that the metal washers failed frequently and had to be replaced after less than two months of service, a costly operation since the two mills require a total of 80 washers. The nonmetallic washers have been in service for four years without failure.

Made by Polymer Corp., Reading, Pa., the special nylon has, in addition to sufficient strength and rigidity to resist deformation and compression, the advantage of permanent lubrication. Its low coefficient of friction results in less heat buildup which would otherwise be transferred to the steel bearings.

Another nonmetallic material, a high-strength plastic known as Celcon, has been introduced by Celanese Corp. of America, New York. The acetal copolymer has been successfully extruded and blow molded. Field tests have proved it to be economical for injection molding. The new plastic has the engineering properties (hardness, stiffness, dimensional stability) and resistance to chemical attack which will make it useful for such applications as decorative and functional trim in automobiles, machinery gears and bushings, housings for business machines, in appliances, pumps, hose couplings and containers.

Applications for still another nonmetallic material called Delrin, produced by DuPont, continue to grow. The acetal resin is being molded into instrument housings for the Valiant (2 lb. of it replace 9 lb. of zinc) and it is being used in pumps, oil field pipe, aerosol containers. In other countries, Delrin is formed into shoe heels, pen mechanisms, toothbrush handles and lawnmower wheels.

NYLON SOLVES PROBLEM IN ROLLING MILL
Thrust Washers of Permanently Lubricated Nylon Outlast Metal Counterparts

From Here and There

Nonmilitary uses for titanium are growing, and to stay ahead of the pace Titanium Metals Corp. of America will add $2 million worth of new facilities at its Toronto, Ohio, plant. The new equipment will produce titanium tubing — seamless and welded and re-drawn — primarily for chemical processes. Sizes will range from ½ to 3 in. diameter in lengths up to 30 ft.

• • • •

More progress has been made toward better corrosion resistance of automobile trim with the introduction of a new stainless alloy, Type 433. The alloy is basically Type 430 with additions of molybdenum and copper which give it better resistance to de-icing salts used on highways today. Potential uses for Type 433, according to metallurgists at Allegheny Ludlum Steel Corp., who are responsible for the alloy composition, also lie in the architectural, furniture and appliance fields.

Advances in Vacuum Technology

The need for steels with fewer inclusions and lower gas contents than air melting provides has resulted in a number of effective melting techniques, most of them based on vacuum technology. In a new method, described in *Metal Progress* next month in a special report on advances in this area of steelmaking, the metal is deoxidized in a vacuum with excess carbon being employed as the deoxidizing agent rather than silicon and aluminum. The report will also bring you up to date on consumable-electrode vacuum-arc melting where the trend is toward larger ingots. In addition, a method for protecting degassed steel while it is being teemed will also be described. In this process, the metal is poured into ingot molds filled with argon.

New Ideas on Aerospace Materials Highlight Western Metal Congress and Exposition

LOS ANGELES — Engineers concerned with heat treating specialty steels and high-temperature alloys are finding that these materials can often be protected from damaging scale formation by coatings applied before heat treatment. The economic advantage is particularly important in metalworking plants where production quantities are not high enough to warrant installation of atmosphere and vacuum furnaces.

In making this point, Etric L. Stone, project chief, Boeing Airplane Co., stated that the value of protective coatings during heat treatment has only recently become an important production technique. Mr. Stone addressed a panel session on heat treating methods last month at the 12th Western Metal Congress and Exposition sponsored by the American Society for Metals.

New Scale Conditioners

At Boeing, two new oxidation-inhibiting coatings have been investigated. (A report, prepared by Mr. Stone and L. Albertin on Boeing's work with protective coatings, will appear in the June issue of *Metal Progress.*) It was found that silicone oil, although best on stainless steels, can also be used on other metals (titanium excluded); clay suspension coatings are predominately for cobalt and nickel-base alloys.

Most effective of the silicone fluids or greases is dimethylsiloxane polymer brushed or rolled on. When applied to stainless steel before annealing, it protects the surface of the metal so that only 0.1 to 0.2 mil of metal is lost. This compares with a loss of 0.5 to 1.5 mils on unprotected surfaces. Silicone coatings also reduce final pickling time about one fifth to one tenth that required of non-coated material.

Clay suspensions are applied as a spray to a uniform thickness of 0.2 to 0.5 mil. Parts must be handled carefully after the coating is cured and the suspension should be applied only to clean surfaces.

For protecting titanium alloys and stainless steels during heat treatment, Boeing engineers have found glass coatings to be effective. Aluminum paint dried at 400° F. and baked 24 hr. at 1200° F. can also be employed (Fig. 1). It is removed after heat treating by alkaline and pickling solutions.

Furnace Design

The techniques being employed to give more efficient heat treating were discussed at the panel session by Orville E. Cullen, Surface Combustion Div. of Midland-Ross Corp. He emphasized the advantage of "power convection" to accelerate heat transfer by rapid movement of the furnace atmosphere. For example, one of the recent innovations in furnace designs is to install a radial flow fan without diffuser or shrouding in the roof of a batch furnace or in separate zones of continuous gas carburizing or other controlled-atmosphere furnaces. This arrangement has the advantage of supplying a high-volume flow of heated atmosphere under the hearth with sufficient static pressure to make it penetrate up through dense loads.

He also pointed out that it is possible to calculate with accuracy the flow requirements needed to maintain good heat transfer and desired chemical balance between atmosphere and work, but the determination of resistance to flow through the work load is not always easily solved. According to Mr. Cullen, research has come to our aid in reducing this problem to workable formulas which correlate fan delivery with flow resistance and the permissible depth of the work load.

Alloying During Welding

Changes in the composition of weld metal and at the interface where weld meets base metal should be getting a lot more attention from welding engineers, according to G. E. Linnert, Armco Steel Corp. who discussed alloying during welding at the session on process metallurgy.

One of the examples he described involved the dilution which occurs when weld overlays of stain-

less steel are made on carbon steel. This represents alloying in reverse; the overlay composition is quite different than that of the electrode, and it does not always possess the desired corrosion resistance. The answer lies in minimizing penetration into the base metal and including extra alloy with the metal being deposited.

Homogeniety, another problem with overlays, has brought on some unexplained corrosion in worn out pulp digesters originally made of carbon steel and put back into service with a stainless steel interior deposited by welding. In one instance, deep furrows through the overlay were first attributed to corrosion at areas where weld beads did not overlap; yet their true cause proved to be nonuniform chromium distribution and small cracks in the stainless steel overlay. Homogeniety can be assured by maintaining constant welding conditions (principally, welding speed) and by keeping the weld pool molten long enough to allow thorough mixing.

Welding Molybdenum

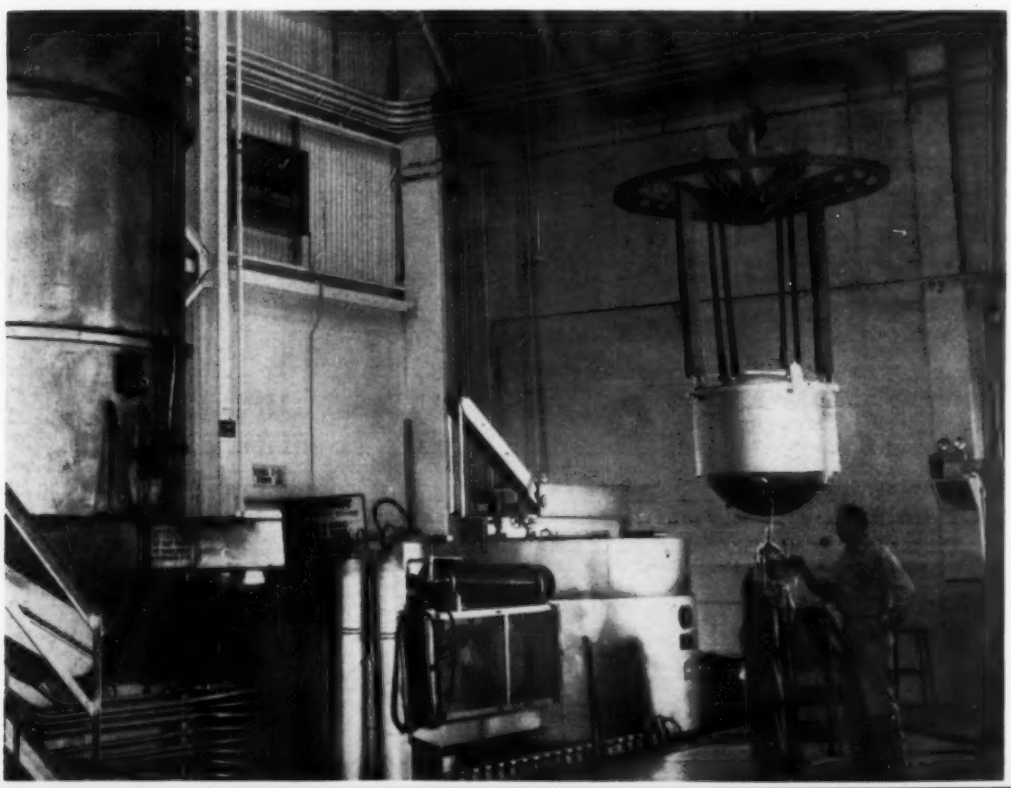
Interest in refractory metals as structural materials that will hold up at high temperatures has motivated study of advanced fabrication techniques. It has been shown that electron-beam welding offers two advantages – weld metal cleanliness and high heat density – which are important, particularly when dealing with difficult-to-weld metals. In discussing the welding of 0.5% Ti molybdenum sheet, Ernest G. Thompson, Rocketdyne, stated that the process holds promise for welding metals such as this alloy which are otherwise easily embrittled by oxygen, nitrogen and hydrogen. Mr. Thompson, formerly with Marquardt Corp., reported on preliminary work at Marquardt on evaluating the ability of electron-beam equipment to join molybdenum sheet.

Tests showed that, compared to inert-gas tungsten-arc welds, those made with electron-beam equipment had smaller grains, less porosity and were more ductile. Much narrower fusion and heat-affected zones were also achieved. It is interesting to note that welds made by high-voltage apparatus (100 kv.) had the narrowest heat-affected zones, but a number of them cracked when roll planished after being heated to a dull red color. This points out the need for stress relief immediately after welding.

Tensile Tests

Tensile tests revealed no difference in welds made by either high or low-voltage (25 kv.) equipment. Strengths of parent and weld metal drop off sharply above 2000° F., level off at about 2700° F. and then drop again. Complete recrystallization occurs within 5 min. at 2400° F. and above, and since the effect of cold work is removed at these temperatures, the parent and weld metal are of equivalent strength. Ductility of the weld improves from about 2% at room temperature to about 14% near 1800° F. The parent metal exhibits gradually decreasing ductility from about 14% at room temperature to 3% when heated to 1600° F. It increases steeply as temperature goes above 2000° F.

Fig. 1 – Aluminum Paint Applied to Titanium Pressure Vessels Helps Prevent Formation of a Tenacious Scale on the Metal During Heat Treatment. It is one of the methods, described by Etric L. Stone, Boeing Airplane Co., for conditioning or preventing scale on specialty steels and titanium



How To Judge Value

Value engineering is not a substitute for other cost reduction methods; it supplements them. Described as a management discipline before a panel session at the Metal Congress, its aim is to emphasize the importance of the dollar in the design equation. Panel chairman E. D. Heller, Convair Div. of General Dynamics Corp., defined value as the lowest cost to achieve an essential function. If, for example, the cost of an item exceeds the worth of the required function, then maximum value has not been achieved. This simple comparison, when considered along with possible alternatives and their cost, makes up a basic approach to the concept of value analysis.

Metals at Low Temperatures

Brittle fracture, although certainly not a new problem to metals engineers, has taken a more dominant role in affecting alloy selection because of our expanding use of metals at cryogenic temperatures. An apparatus used for testing metals at low temperatures was described by R. M. McClintock, Convair (Pomona) Div. of General Dynamics Corp. The basis for the instrument is a stainless steel dewar vessel 16 in. high and 5¾ in. in diameter in which tensile tests can be made on specimens cooled (with liquid helium) to as low as 4° K. (−452° F.).

Mr. McClintock also described some of the characteristics of metals at low temperatures. He pointed out that almost all solid materials increase in strength as temperature drops. Why this occurs in metals is due to the lowering of thermal energy which assists the motion of dislocations, the major mechanism by which deformation occurs. Thermal and mechanical systems can account for exceptions to the rule.

Yield strength of ductile materials follows a pattern similar to that of tensile strength. Near −43C° F., the yield strength of fcc. and hcp. metals has increased by one to three times. In bcc. metals the increases are greater and often are so rapid that yield strength becomes greater than fracture strength; the metal fractures before it yields. Thus, the sign of embrittlement is shown by yield and tensile strength curves which converge as temperature is lowered.

Ductility is, of course, also affected by low temperatures. Generally, bcc. metals (low-alloy steels, molybdenum, columbium) become brittle; fcc. metals (such as copper, nickel, copper-nickel alloys, aluminum, austenitic stainless steel (with more than 7% nickel) remain ductile if they were so at room temperature. Metals with hcp. structure fall between these extremes. Zinc becomes brittle in tension; zirconium and titanium remain ductile.

Micrometallurgy

One of the relatively new tools in metallurgy is the electron-probe microanalyzer. Because it has the ability to determine compositions of regions only microns in size, the instrument will provide answers to many unsolved problems in metallurgy such as the identity of phases, segregates and inclusions. Described by David B. Wittry, University of Southern California, the analyzer uses a highly focused electron beam to bombard the surface of the specimen. The x-rays which are thus produced are then analyzed.

There are numerous potential applications for the electron-probe microanalyzer. It can be used, for example, to study grain-boundary diffusion in solids. Figure 2 shows the results of an electron probe study (made by L. S. Birks of the U. S. Naval Research Laboratory) on a specimen of copper which was heated with 70-30 brass in vacuum at 550° C. (1020° F.) for 28 days. The lines of constant zinc concentration plotted beside the micrograph indicate the extent of diffusion along the grain boundary.

In studies of semiconductor alloy systems and in physical metallurgy, the potential is great since the analyzer can be employed to determine nonequilibrium conditions, diffusion processes, phase changes and the influence of impurities. Mr. Wittry also stated that the determination of carbon, oxygen and nitrogen by electron-probe analysis will soon be possible.

Vacuum-Induction Melting

According to I. S. Servi, director of research at the Metals Div. of Kelsey-Hayes Corp., vacuum-induction melting can produce steels and superalloys containing 10 ppm. oxygen and nitrogen, 0.2 ppm. hydrogen and less than 5 ppm. arsenic, bismuth, antimony, cadmium, zinc, tin and lead. Manganese and silicon can also be kept below 0.10% because these elements need not be added as deoxidizers. The reactive elements such as aluminum and titanium, often added for alloying, can be controlled to within ±0.05%.

Dr. Servi expects vacuum-induction melting to show steady growth mainly because of efforts aimed at adapting the process to manufacture of a greater number of products and acceptance of double melting in which metals are first compounded in vacuum-induction furnaces and the resulting ingots are remelted by the consumable-arc process.

Ingots weighing about 4500 lb. can be poured but by 1962 this figure may reach 9000 lb. Vacuum-induction melting is being used primarily in the production of low-alloy steels, chromium hot work die steels, stainless steels and iron and nickel-base superalloys. It is especially beneficial to notch sensitivity, ductile-to-brittle transition temperature and fatigue strength. For example, the ductile-to-brittle transition temperature for air-melted, low-alloy steels is about 100 to 300° F. but is lowered to −30 to −150° F. in vacuum-induction melted stock.

This problem of toughness takes on tremendous importance in metals that are being used at their highest possible strength levels as in rocket motor cases. J. A. Brown, Aerojet-General Corp. said that consumable electrode vacuum arc melting of alloy steels usually (but not always) improves their toughness compared with air melting. It also reduces the difference between longitudinal and trans-

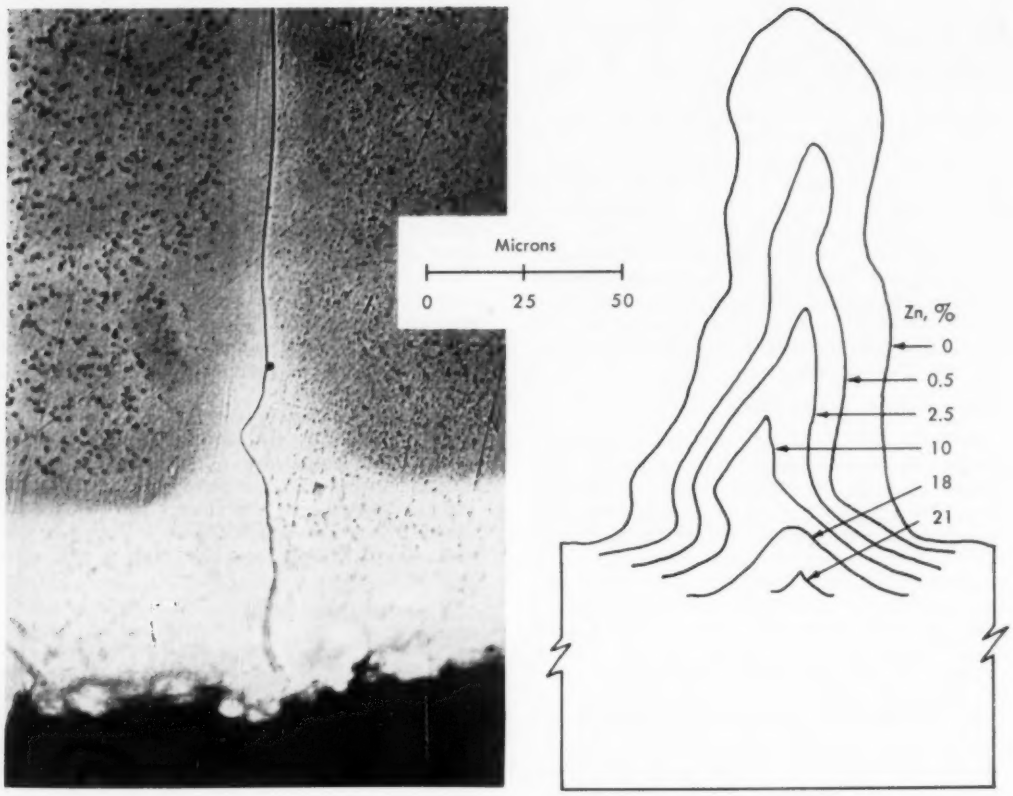


Fig. 2 – Study Made by L. S. Birks, U. S. Naval Research Laboratory, of Diffusion of Zinc Between Two Grains of Copper Demonstrates a Useful Application for Electron Probe X-Ray Microanalyzer. The instrument and its use in the metals industry were described by David B. Wittry, University of California

verse toughness thus permitting engineers to establish with more assurance just what design strength can be used.

Materials Technology

At the aerospace materials session, Nathan E. Promisel, chief materials scientist and director of materials section, U. S. Navy Bureau of weapons presented new data which showed that the ductility of beryllium can be improved greatly by repeated zone refining. The discussion of cryogenics (see p. 65) indicated the need to develop alloys specifically for ultra low temperature service. The session on aerospace materials will be reported in detail in future issues of A.S.M. Publications.

Progress Revealed At Show

Visitors to the metal show learned about new materials for aerospace applications and gained new ideas on fabrication techniques. Graphite cloth on display is being applied in high temperature missile components. Recent processing improvements have increased the previous 8-lb. per in. average breaking strength of this material to 25-lb. per in. and at the same time have doubled the flexibility. Also displayed was a piece of sheet beryllium rolled from a cast billet and samples of beryllium oxide parts joined by a bonding agent stronger than the parent metal. This new joining method is expected to expand applications for beryllium oxide in the electronics industry.

Molybdenum alloys are finding new uses in the missile, space and nuclear fields; large molybdenum parts formed from sheet by spinning were displayed. Show visitors saw a demonstration of a new coating for molybdenum which protects against oxidation to over 2400° F. in air. Also, shown were samples of tantalum in contact with platinum in an area ratio of up to 10,000 tantalum to 1 platinum which were immune to embrittlement for more than 1000 hr. in concentrated hydrochloric acid at 374° F. Ordinarily tantalum is embrittled in a few hours in this environment.

Information was available on a new 18% nickel steel which develops a yield strength of 250,000 psi. by an age hardening mechanism known as "maraging." Containing 7% cobalt, 5% molybdenum, less than 0.5% titanium and 0.05% carbon (maximum), the alloy can be welded in the heat treated condition without the need for preheat.

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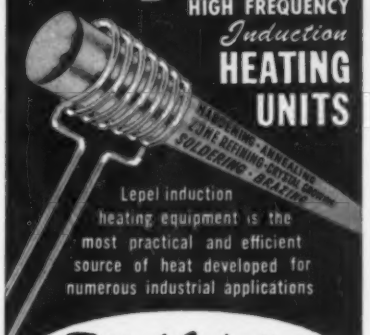

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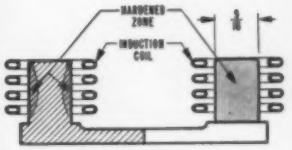

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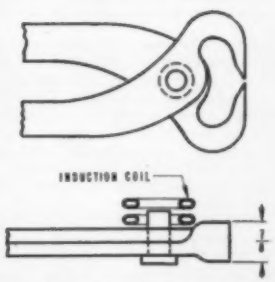

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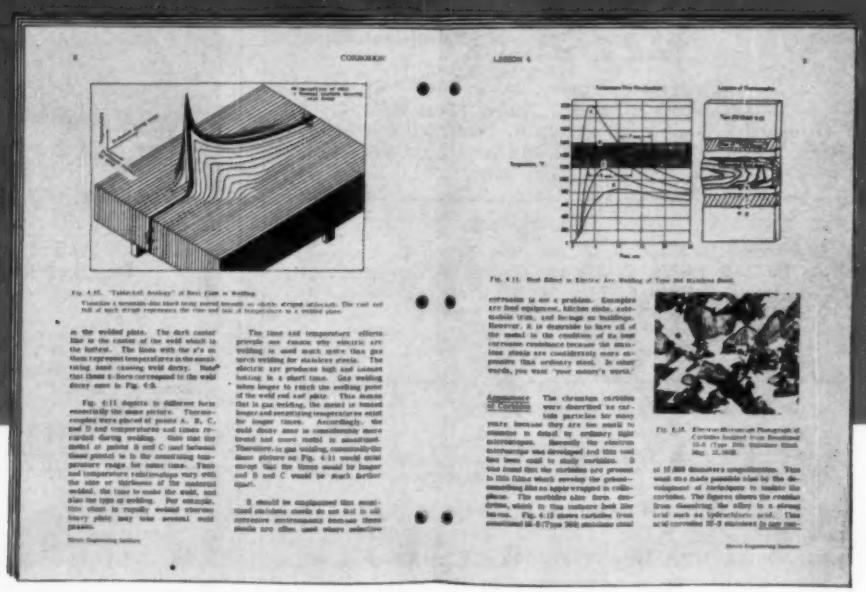

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Dr. Fontana graduated from the University of Michigan with a B.S. in Chemical Engineering, and a Ph.D. in Metallurgical Engineering. From 1934 to 1945 he served as metallurgical engineer and supervisor in the Engineering Department, E. I. du Pont de Nemours and Co., Inc., Wilmington, Delaware. He is presently Professor and Chairman, Department of Metallurgical Engineering; Director, Corrosion Research Laboratories, Engineering Experiment Station, Ohio State University.

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9. Corrosion Tests
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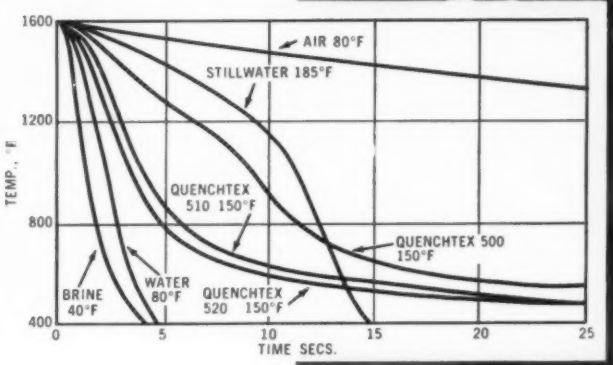
Cooling rates of several quenching media including QUENCHTEX 500, 510 and 520.



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In forgings such as these, heating and cooling operations must be carefully controlled to assure proper structure in the steel. Using the skill that only time and experience could give him, Al Sauer, a veteran in our Homestead Works, supervises the careful heat treating of these forgings. After heating, they are transferred to the 50′ high cooling tower where they are cooled at controlled rates. Then they go back for further machining, testing, boring, more heat treating, final machining, sonic inspection, and shipment.

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United States Steel Export Company

Shown here are four of the seven new vertical heat-treating furnaces, housed in a modern 125 foot high building, that give United States Steel the ability to handle the largest generator and turbine rotor forgings that can be made.

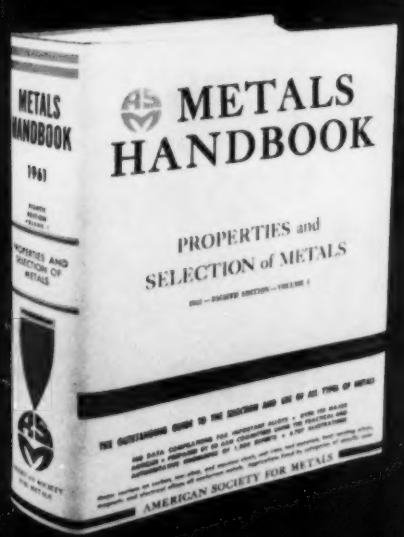
One of the world's largest generator forgings being machined in our 120-inch lathe. After final machining, it weighed 114 tons.

USS United States Steel

TRADEMARK

CONSULT THE

NEW



METALS HANDBOOK

on Properties and Selection of Metals

for ENGINEERING—
PRODUCTION
MANAGEMENT—
PLANNING—
MECHANICAL DESIGN

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AMERICAN SOCIETY FOR METALS
Metals Park, Novelty, Ohio

ANOTHER NEW DEVELOPMENT IN TESTING MACHINES

WIEDEMANN-BALDWIN MARK E

The latest in a continuing series of Wiedemann-Baldwin new testing developments is the Mark E, primarily a tension testing machine consisting of a single unit assembly containing the Loading System, Load Measuring Cell and Load Indicator. Adaptors for compression testing can be supplied, if desired.

The Loading Frame has been designed for a maximum capacity of 10,000 lbs., and multi-range indicators having maximum capacities of 10,000 lbs., 1,000 lbs., and 100 lbs. are available.

Included in its features is the positive guiding of the loading head, precise SR-4® load weighing system unaffected by crosshead guiding, 12" per min. maximum testing speed, elongation counter, automatic return, full range of accessory equipment for all testing requirements.

This electro-mechanical unit is designed for production testing . . . quality control . . . research/development. Take advantage of the high performance standards for accuracy, quality and dependability assured in the Wiedemann-Baldwin Mark E. Write today for detailed literature.

WIEDEMANN BALDWIN®

WIEDEMANN MACHINE COMPANY
GULPH ROAD • KING OF PRUSSIA, PENNSYLVANIA

Sales Offices: Mount Vernon, N. Y.; Silver Spring, Md.; Pittsburgh; Chicago; San Francisco; in Canada: Peacock Bros., Montreal.

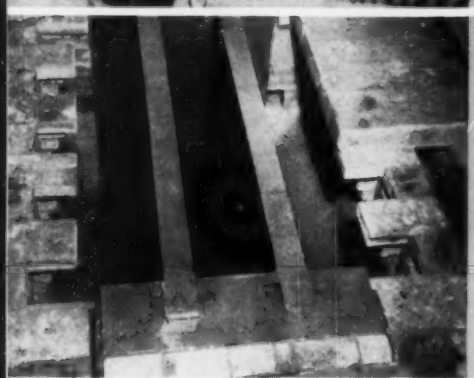
Circle 1535 on Page 48-B

Report from Carborundum:

How industry is solving unusual problems with unusual refractories

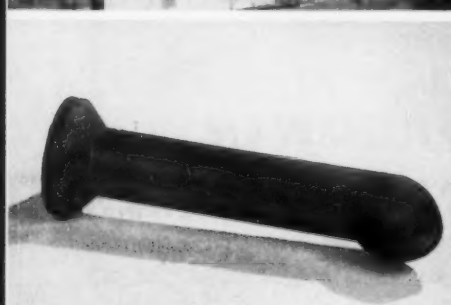
PACKING EXPANSION JOINTS:

CERAMIC FIBER WITHSTANDS 2300°F; EASILY PACKED; OBTAINABLE IN MANY FORMS. FIBERFRAX® ceramic fiber extends the temperature ceiling of fibrous insulating materials; opens new application areas. In rope or bulk form, it makes an excellent expansion-joint packing for refractory furnace walls. It is light in weight, highly resilient, does not shrink, is impervious to heat shock, and is inert to most furnace atmospheres. Various forms of FIBERFRAX — e.g. cloth, board, paper etc. — also offer advantages for gasketing, sealing, wrapping, lining, encapsulating, blanketing and jacketing.



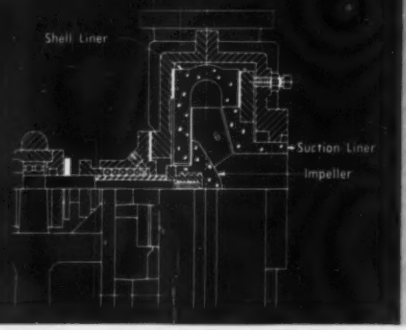
ZINC ORE REDUCTION IN VERTICAL RETORT:

RUGGED REFRACTORY WALLS CONDUCT HEAT FAST, STAY GAS TIGHT. Five million Btu's must be transferred through refractory walls such as shown at left for every ton of zinc produced. High heat conductivity — 11 times that of firebrick — is provided by CARBOFRAX® silicon carbide retort walls. Internal temperatures reach 2000°F. Other important refractory properties: great physical strength at high temperatures, chemical inertness, and unequalled abrasion and erosion resistance. Low permeability is also important because gas-vapor mixtures produced in the retort must be contained.



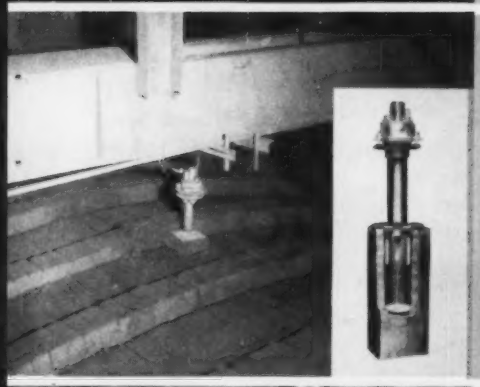
SPRAY NOZZLE FOR CORROSIVE SERVICE:

REFRACTORY REPLACES METALS—RESISTS HIGH TEMPERATURES, CORROSION, THERMAL SHOCK. The nozzle illustrated sprays a 15% solution of SO_2 in water at 150°F into a chamber operating at over 1700°F. Conditions involve severe thermal shock and corrosion. Previously used metal nozzles often lasted less than two months. Nozzles made of Carborundum's silicon carbide have shown no signs of failure after **five years** of service — another example of how these versatile refractories can take unusual forms to meet highly specialized problems.



PUMPING ABRASIVE SLURRIES:

REFRACTORY PARTS FOR PUMP RESIST WEAR, OUTLAST HARDEST METAL ALLOYS. Development of REFRAX®, a silicon-nitride-bonded silicon carbide, makes it possible to use refractories in many applications usually requiring metals. It can be formed with high dimensional accuracy as well as a high finish. Examples of use are impellers and shell liners in "Lightning" sand and gravel pumps made by Kansas City Hay Press Co. Comparative performance during a six months' test pumping 150 GPM of water with 20% silica sand against a 70-foot head has shown that REFRAX parts give more than **five times** the life of duplicate parts made of nickel chrome alloy.



MAKING 200 TONS OF STEEL BEHAVE:

TARGET BLOCK HELPS KEEP FURNACE TEMPERATURE AT MAXIMUM PRODUCTION LEVEL. The temperature detector shown in the open hearth roof at left is mounted in a hollow silicon carbide block. The detector is focused on a target disc made of another one of Carborundum's refractories — REFRAX refractory. Radiated heat from the disc provides a constant check on roof temperature . . . assures maximum production without danger of "losing" the roof. These two refractories provide the necessary properties of high heat conductivity, resistance to high temperatures and furnace gases and exceptional hot strength. Device is manufactured by Leeds & Northrup Co.

FIRING ELECTRICAL PORCELAINS:

SILICON CARBIDE KILN FURNITURE SIMPLIFIES CAR SETTINGS, PROTECTS WARE; IMPROVES HEAT CIRCULATION. Kiln car at left is loaded with electrical insulators supported by CARBOFRAX silicon carbide tile, posts and girders. Setting enables car to carry maximum load; may be rearranged as needed to suit different sizes of ware. CARBOFRAX furniture possesses high hot strength, resists deformation, reduces breakage losses — in trip after trip through the kiln. Furniture is also designed to permit uniform circulaton of heat through and around car for best ware firing conditions.

SINTER-PLANT DUST COLLECTOR:

REFRACTORY LINING LASTS YEARS IN SERVICE INVOLVING HIGH-VELOCITY GAS AND ABRASIVE PARTICLES. Superior resistance to entrained abrasive particles is shown by a lining made of a Carborundum-made refractory in this primary dust collector. Cone lined with Carborundum's material has handled more than 2,500,000 lbs of abrasive sinter dust in **seven years.** Ordinary brick in other parts of the same collector has worn back to the shell in only 5 months. Other wear-resistant applications for Carborundum's refractories are in duct linings, blast furnace downcomers, hydro cyclones, chutes, bins, feeder tables, gas scrubbers, nozzles and other related applications.

Want help on your problems?

Carborundum engineers will be glad to recommend refractories to answer your specific needs. For information, contact Dept. M-41, Refractories Division, Carborundum Co., Perth Amboy, N. J. Descriptive brochures available on request. Please specify the area or areas of particular interest to you.

for engineered refractories . . . count on

Circle 1536 on Page 48-B

CARBORUNDUM®

Riehle

...universal testing machines

WITH A FUTURE

RIEHLE 120,000 lb. Universal Hydraulic Testing Machine

RIEHLE offers complete instrumentation and accessories for testing materials over a wide range of temperatures. This includes vacuum furnaces for tests up to 5000°F., cryostats for tests down to 4°K., a full range of specimen holders and tools, automatic strain rate and load rate controls and load cells.

RIEHLE offers sensitive, rapid response testing machines in both screw power and hydraulic types in capacities from 2,000 to 450,000 lbs.

RIEHLE Electro-Balanced Indicating Unit—the most versatile, accurate indicating system on the market—is available for both types of testing machines.

RIEHLE Testing Machines are floor-mounted . . . no special foundation required.

RIEHLE combines ruggedness and sustained accuracy with inherent long, trouble-free service by using the most advanced methods in modern engineering technology and fabricating practices.

RIEHLE maintains a national field calibration service for complete and dependable certified inspection and calibration.

RIEHLE engineers often save project time, capital investment and labor costs by recommending testing procedures and equipment to meet specific requirements. Write for Bulletin RU-2-60. Address Dept. MP-461.

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RIEHLE TESTING MACHINES DIVISION OF

American Machine and Metals, Inc.

EAST MOLINE, ILLINOIS

RIEHLE also builds Creep and Stress-Rupture Testing Machines, Hydraulic Fatigue Testing Machines, Construction Materials, Impact, Brinell, Torsion, Horizontal Chain, Rope and Cable Testers and Portable Hardness Testers for Rockwell Readings.

Divisions of American Machine and Metals, Inc.

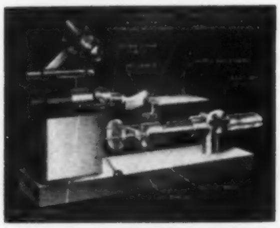
TROY LAUNDRY MACHINERY • RIEHLE TESTING MACHINES • DE BOTHEZAT FANS • TOLHURST CENTRIFUGALS • FILTRATION ENGINEERS • FILTRATION FABRICS NIAGARA FILTERS • UNITED STATES GAUGE • RAHM INSTRUMENTS • LAMB ELECTRIC COMPANY • HUNTER SPRING COMPANY • GLASER-STEERS CORPORATION

Circle 1537 on Page 48-8

NEW PRODUCTS

Heat and Corrosion Resistant Materials

High-Temperature Materials Testing



This standardized, calibrated apparatus tests and screens materials for use in thermal protection systems. As a high-velocity, high-temperature jet of air impinges on the sample, instrumentation permits measurement of front and back face temperatures of the sample, as well as heat flux and gas velocity. Operating in the 30 to 200 kw. power range, the unit produces gas streams with speeds up to 10,000 mph., and stagnation pressures from 1 to 20 atmospheres. In determining thermal shock resistance and ablation characteristics, materials are subjected to environments ranging from that seen by the leading edge of a high-Mach number plane (B-70) to that encountered by the nose cone of a re-entering Atlas missile. *Thermal-Dynamics Corp.*

For further information circle No. 1277 on literature request card, p. 48B

Industrial Heating Equipment

Automatic Heat Treating

The "Clean-Line" furnace, an automatic heat treating unit, provides "straight-through" operation from loading to quenching. Available in six standard sizes, a complete system consists of a load and transfer mechanism, heat treat furnace, atmosphere cooling chamber, and an oil-quench tank and elevator. The equipment, gas-fired or electrically heated, can be used for carbonitriding, carburizing, bright hardening, annealing, normalizing, or brazing of metal up to 1850° F. *Hevi-Duty Electric Co.*

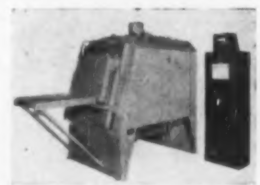
For further information circle No. 1278

Furnace Element for Service at 3000° F.

A silicon carbide-molybdenum disilicide heating element, "Super Hot Rod", can be operated up to 1700° C. (3090° F.) without a protective atmosphere. The hot zone of a tubular Hot Rod is formed by a spiral cut through the wall of the tube. Because of improved oxidation and thermal shock resistance, the element has longer life than conventional silicon carbide rods at operating temperatures of 1500° C. (2730° F.). The high-temperature strength of a Hot Rod permits horizontal installation. *Norton Co.*

For further information circle No. 1279

Controlled Atmosphere Box Furnace



Available in gas-fired, oil-fired, or electrically heated models, a controlled atmosphere box furnace for tool room applications can maintain a temperature of 2250° F. (2400° F. in a smaller unit). A ceramic fan produces 100% forced convection, which provides temperature uniformity. Ceramic heating tubes are impervious to high-carbon and high-hydrogen atmospheres. ***Ipsen Industries, Inc.***

Circle No. 1280 on request card, p. 48B

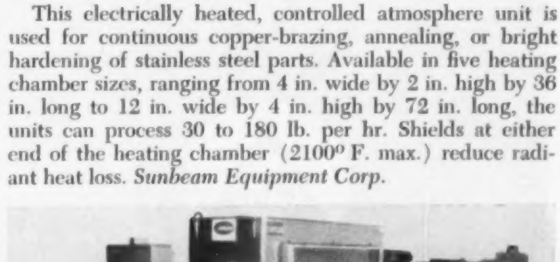
Heat-Processing Units

Designed for heavy and continuous duty up to 2500° F., the "SM-AD Series" heat treating furnace features rapid heat-up and recovery plus flexibility of heating cycles. Available in a range of sizes with a choice of controls, the unit can operate efficiently in the shop, tool room, or laboratory. Silicon carbide heating elements, mounted over and under the chamber, assure uniform heat transfer. The side-hinged doors, air-operated, are controlled by a foot pedal. *Pereny Equipment Co.*

For further information circle No. 1281

Conveyer Muffle Furnace

This electrically heated, controlled atmosphere unit is used for continuous copper-brazing, annealing, or bright hardening of stainless steel parts. Available in five heating chamber sizes, ranging from 4 in. wide by 2 in. high by 36 in. long to 12 in. wide by 4 in. high by 72 in. long, the units can process 30 to 180 lb. per hr. Shields at either end of the heating chamber (2100° F. max.) reduce radiant heat loss. *Sunbeam Equipment Corp.*

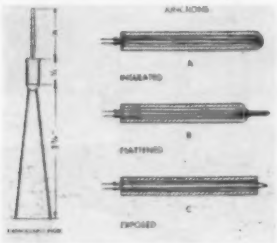


Circle No. 1282 on request card, p. 48B

FAHRITE
HEAT AND CORROSION Alloys
centrifugally
cast tubes
FAHRITE centrifugally cast tubes are available in a wide range of diameters, lengths and wall thicknesses for many types of service. Ohio's exclusive use of permanent molds, plus the latest production facilities and foundry techniques, provides outstanding uniformity.
ALLOY CASTING INSTITUTE
ACI
MEMBER
• Radiant Tubes for Furnace Heating
• Roller Hearths for Heat Treating Furnaces
• Tubular Hearths for Batch Type Furnaces
• Hold-Down Rollers for Pickling Operations
• Sleeves — and many other essential alloy parts.
THE OHIO STEEL FOUNDRY CO.
SPRINGFIELD, OHIO
Plants at Springfield and Lima, Ohio
OSF 2

Circle 1538 on Page 48-B

Miniature Thermocouples



To meet the increasing demand for fast, accurate temperature-measuring instrumentation, *Baldwin-Lima-Hamilton* is offering a line of "HT Micro-Miniature" thermocouples suitable for use in the range from cryogenic temperatures to +3000° F. A response time of 13 millisec. has been achieved with an exposed junction. Typical applications include measurement of skin temperature on missiles, and blade or disc temperatures on jet engines.

For further information circle No. 1283 on literature request card, p. 48B

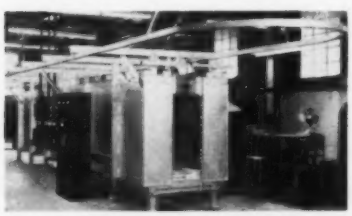
Electric Furnace Control

A constant-phase power amplifier control provides exact, micro-second temperature regulation of electric furnaces. The compact "pHayes-master" employs transistor circuitry to vary the voltage and provide instantaneous control. The unit can be triggered manually or with a millivoltage signal generated by a temperature bulb, dew point or pH analyzer, or other sensitive transducer. Standard capacities are 10, 15 and 70 amp., 115 or 230 volts, using single-phase or three-phase power. *C. I. Hayes, Inc.*

Circle No. 1284 on request card, p. 48B

Continuous Enameling Furnace

This 30-ft. furnace, which has its own built-in overhead conveyer, is used for continuous firing of sheet metal panels (both undercoat and final enamel coat). The variable-speed conveyer permits firing different types of enamels at different rates. The electrically heated, 225 kw furnace consists of three sections: a 6-ft. preheat unit, an 18-ft. firing section (3-phase heating circuits with elements mounted on both sidewalls), and a 6-ft. cooling chamber. *The Waltz Furnace Co.*



For further information circle No. 1285 on literature request card, p. 48B

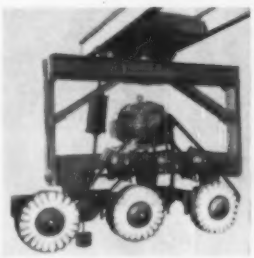
Cleaning and Finishing

Vibratory Finishing Equipment

The "HD-1016" vibrator, made by *Lord Chemical & Equipment Div.*, can be tilted for rinsing while still vibrating. This results in a faster, more thorough rinsing operation and, in combination with a special top screen, facilitates separation of fine or fractured chips from the rest of the media. Amplitude and frequency are variable within the range 0 to ¼ in. amplitude and 700 to 2100 cycles per sec. The 1 cu. ft. model, rubber-lined, is driven by a 2-hp., 1800 rpm. motor operating at 220/440 or 550 volts on 3-phase 60-cycle current.

For further information circle No. 1286 on literature request card, p. 48B

Three-Wheel Work Head

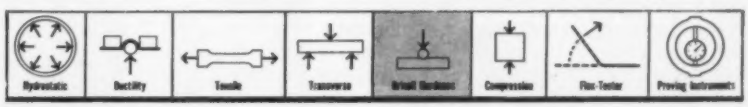


Designed to buff and polish difficult curvatures on parts which are hard to process with floor-mounted equipment, this compact work head is suspended from an overhead carriage. Each of the three wheels floats independently of the other; uniform work pressure is maintained by individual air cylinders or by an automatic torsion balancing unit. Vertical positioning of complete head is possible and either individual or unison wheel-wear adjustment may be specified. *Murray-Way Corp.*

For further information circle No. 1287

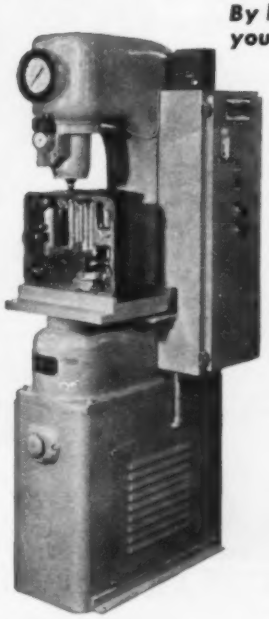
Three-Stage Cascade Rinse Unit

Precision cleaning techniques are required by manufacturers of semi-conductors and precision electromechanical equipment. In a three-stage unit made by *Pioneer-Central Div., Bendix Corp.*, rinse solution is pumped into the first station, overflows into the second, and then into the third, where it is finally drained, rejuvenated and re-



hardness tests increase plant capacity

By knowing the hardness of incoming parts you can reduce number of processing steps



Every production program has a bottleneck. Steel City Brinell testers can stop the broken-tool bottlenecks caused by too-hard parts.

For example, a maker of transmission cases has solved two problems with one "Color-Glance" tester. All incoming cases are tested; only hard ones need be annealed. Tool breakage is minimized, and limited annealing capacity is not overloaded.

Steel City "Color-Glance" Brinell hardness testers are high-production units. Relative hardness is shown by colored lights to reduce errors and fatigue. Optional equipment: workpiece locators, conveyor sections, counters, etc.

Steel City has solved many hardness-testing problems—laboratory, low-volume, portable. A standard machine may meet your needs.

Tell us your testing problem; ask for literature.

Steel City Testing Machines Inc

8811 Lyndon Ave., Detroit 38, Mich.

Circle 1539 on Page 48-B

NEW MODEL 1220 DYNAPAK

RUGGED POWERFUL EFFICIENT

DYNAPAK MODEL 1220 . . . massive, rugged all-new model of industry's only proven *high energy rate forming* machine! All-new Dynapak saves expensive metal chips — eliminates costly machining.

SAVES METAL
SAVES MACHINING
SAVES TIME

DYNAPAK MODEL 1220 is designed and built to work a full day *every* day . . . efficiently, dependably, economically! Dynapak uses only one-quarter of its available energy to exceed the force of a 6,000-ton press—always has power in reserve. Models with operating capabilities up to 8 strokes per minute are available.

DYNAPAK MODEL 1220 is versatile — makes a wide variety of products ranging from production tooling to complex turbine blades, missile nose cones and tiny precision surgical pins. Tool steel and the exotic "problem" metals become everyday materials to Dynapak's unique capabilities.

DYNAPAK MODEL 1220 can help *you* do a better job of forging, forming, compacting. Dynapak can help you cut costs and improve profits. Find out now about dependable, performance-proven Dynapak — the new concept in *high energy rate forming*. Write, wire or phone for complete information.

GENERAL DYNAMICS CORPORATION / ADVANCED PRODUCTS DEPARTMENT

GD

P.O. Box 6231 • San Diego 6, California

Circle 1540 on Page 48-B

circulated. Parts to be cleaned are submerged in the third chamber, then in the second, and finally in the first (the cleanest).

For further information circle No. 1288 on literature request card, p. 48B

Barrel-Finishing Compound

Minnesota Mining and Mfg. Co. announces a burnishing compound devised to retain the characteristic

"color" of zinc die castings during barrel-finishing operations. The free-flowing soap compound, "Honite 126", is used in conjunction with lightweight "Honite Z-N" tumbling chips, which will not gouge the soft metal. A small amount of the compound is used in the cut-down cycle; then, without rinsing, more compound can be added for the burnishing cycle – thus lowering processing costs.

For further information circle No. 1289

Welding and Joining

Versatile DC Welder

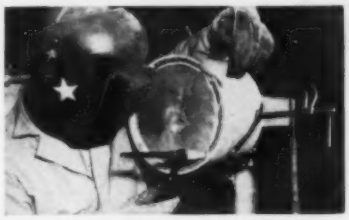
Continuous adjustment of voltage and slope during welding is a feature of the "Sureweld" d-c. unit intro-

duced by *National Cylinder Gas Div.* The "Model DRCP-33" is adapted to high-speed welding of light-gage (0.030 in.) sheet without burn-through. Current as low as 25 amp. at 14 volts can be provided. Rated at 300 amp. (100% duty cycle), the unit has a 115-v. outlet to power automatic control equipment.

For further information circle No. 1290 on literature request card, p. 48B

High Current Air-Cooled Holder

The *Air Reduction Sales Co.* states that the "Airco H16-A" TIG holder is the only air-cooled holder on the



market with a capacity of 160 amp., a-c. or d-c., continuous duty. The H16-A provides rapid, clean welding of thin-gage aluminum, brass, copper, magnesium, nickel, molybdenum, as well as alloy and stainless steel. Aluminum nozzles in a wide range of sizes, have good thermal and mechanical shock resistance. Tungsten electrodes from 0.020 to 5/32 in. diameter and from 2 to 7 in. long can be accommodated.

For further information circle No. 1291 on literature request card, p. 48B

Arc-Plasma Spray Gun

Previously inaccessible surfaces are now easily coated with a compact 25 kw. spray gun, made by

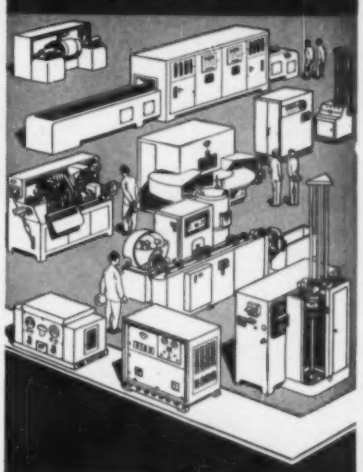
Plasmadyne Corp., which is 2 in. long and 1½ in. in diameter. The 1-lb. gun attains an operating efficiency of 60% in converting electrical energy to heat. It can be employed with standard Plasmadyne consoles and the gun carries a 200-hr. electrode life guarantee, when used with argon. Other models rated at 40 to 80 kw. are also manufactured.

For further information circle No. 1292

Power Supply for TIG Welding

"Balanced wave" a-c. output (equivalent electron flow between electrode and workpiece) in a welder made by *Glenn Pacific Corp.* assures high-performance inert-gas welding with nonconsumable electrodes. This characteristic improves oxide removal (in aluminum welding) and reduces arc fluctuation and sputter. Variable current control is

for HARDENING • BRAZING
SOLDERING • FORGING • ANNEALING
MELTING • SINTERING • WELDING
REFINING • SHRINK FITTING
CRYSTAL GROWING



THER-MONIC

Manufactures the most complete range of

INDUCTION HEATING EQUIPMENT

ELECTRONIC · LOW FREQUENCY
MOTOR GENERATOR

THER-MONIC features

• Over 20 years of concentrated experience.

• Over 5,000 installations.

• Over 15,000 heating applications resolved in our customer service laboratories.

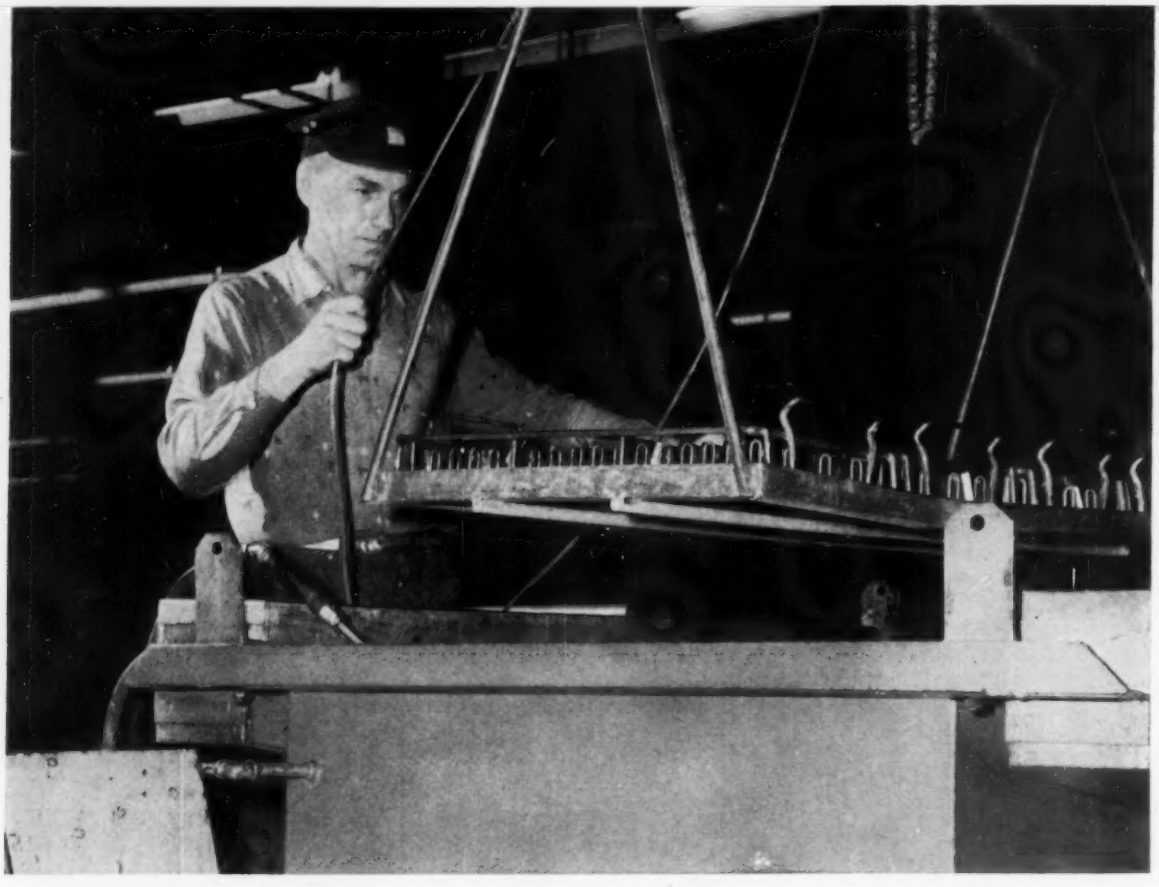
• This outstanding experience and know-how qualify us to prescribe the techniques and equipment best suited for your requirement.

Contact our factory or your local IHC representative.

Write for New 56-page catalog of exclusive features, facts and specs.

INDUCTION HEATING CORP.
181 WYTHE AVE., BROOKLYN 11, N.Y.

Subsidiary of Hathaway Instruments, Inc.
Circle 1541 on Page 48-B



WHERE HOOKER TRICHLORETHYLENE RAISED QUALITY AND LOWERED COSTS

Approximately a year ago, the Metals Processing Division, Curtiss-Wright Corporation, began using high-quality Hooker NIALK® TRICHLORETHYLENE to degrease jet engine blades. Before this, maintaining purity in the baths required frequent cleanouts. Chemical costs were high.

Immediate results with Nialk showed a better cleaning job and tighter quality control. Down time for degreaser maintenance has been substantially reduced.

The exceptional cleaning results now obtained permit inspectors to discover possible flaws more easily. Maintaining quality is far less difficult.

The stabilizer in Nialk TRICHLOR contains *psp*—permanent staying power—which enables the stabilizer to operate efficiently until cleanout. After cleanout, the solvent is distilled for further use in other operations.

Curtiss-Wright officials say that the assistance they obtain from Hooker technical experts in preventing waste is most important, since they are working with costly metals. Because the degreasing baths have never turned acid, problems in keeping their quality at a high level and the necessity to run tests have been reduced. Whatever your degreasing job or the type of metal you're processing, Nialk TRICHLOR can give you a greater volume of work and reduce your costs, as well as provide a smooth-running operation.

Contact your nearest Hooker Chemical Distributor for information. Or write us. We will be glad to help you with any problems.

HOOKER CHEMICAL CORPORATION

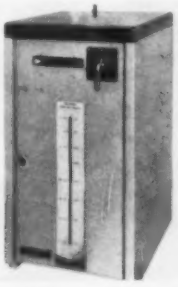
404 UNION STREET, NIAGARA FALLS, NEW YORK

HOOKER CHEMICALS PLASTICS

Sales offices: Buffalo, Chicago, Detroit, Los Angeles, New York, Niagara Falls, Philadelphia, Tacoma, Worcester, Mass. *In Canada:* Hooker Chemicals Limited, North Vancouver, B.C.

Circle 1542 on Page 48-B

provided throughout three ranges: low, 28 to 58 amp.; medium, 53 to 175 amp.; and high, 165 to 400 amp. at 150 v. "Model BW 400-AC" delivers a-c. only, with open circuit voltages of 100 or 150.



"Model BW 400-AC/DC" delivers a-c. or d-c., with open circuit voltages of 150 (a-c.) and 80 (d-c.). Thus it can supply power for TIG and MIG processes, as well as stick electrode manual welding.

For further information circle No. 1293

Four-In-One MIG Torch

A 500-amp. "ST-5" torch for MIG welding—spray arc, short arc, plug, and spot—is offered by *Linde Co.* The torch can be used with all "Sigmatic" machines. Service lines (gas,

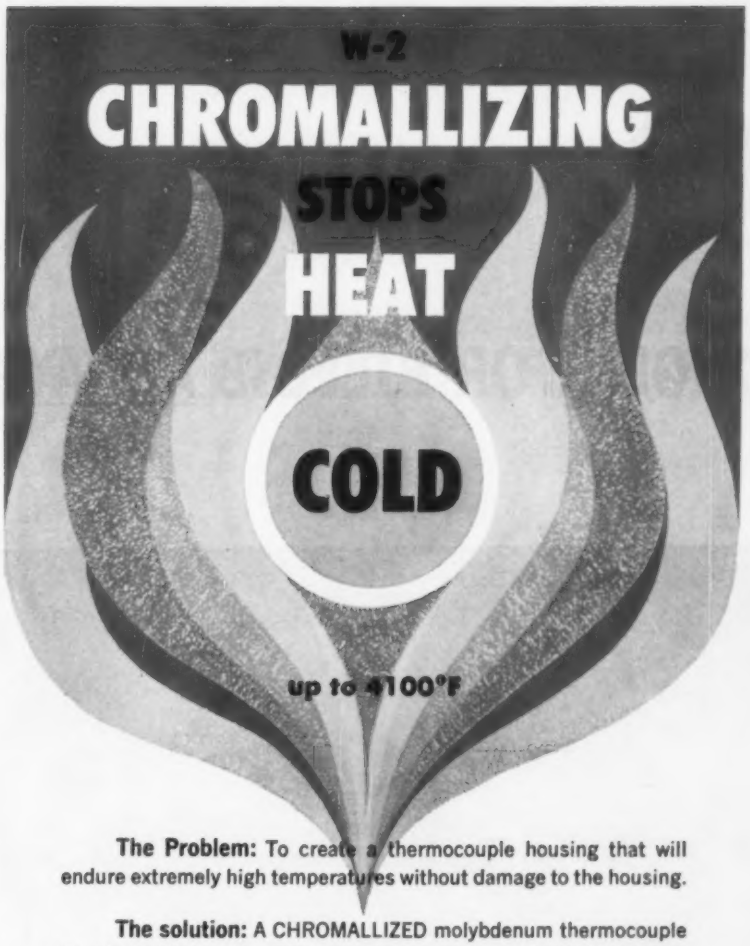
power, water, wire) enter the torch through the rear of the barrel. An efficient cooling system permits continuous welding at 500 amp., even with carbon steel welding wire.

Circle No. 1294 on request card, p. 48B

Nuclear-Grade Aluminum Wire

Aluminum welding and brazing alloys 718, 1100, and 4043 are now available with "nuclear grade" certification. This means they will contain less than 0.008% Li, 0.001% Cd and 0.001% B, which are neutron absorbers, and less than 0.001% Co, which becomes radioactive when bombarded with neutrons. The percentages of Si, Cu and Fe are also kept as low as possible, since they have long half-lives. Alloys are available in rods or spools. *All-State Welding Alloys Co.*

For further information circle No. 1295



The Problem: To create a thermocouple housing that will endure extremely high temperatures without damage to the housing.

The solution: A CHROMALLIZED molybdenum thermocouple housing. This housing withstands temperatures up to 4100°F. Other applications are structural parts for re-entry vehicles, high temperature testing grips, and ramjet engine components.

What is Chromallizing?

A proven process for diffusing chromium and other elements into the surface provides an alloy case which is integral with the base metal. It can't peel or flake. the chromium and other elements diffuse uniformly into recesses, pores, cracks and even blind holes.

CHROMALLIZING processes are also being used to protect superalloys for jet engine parts and to protect ordinary steel against wear, oxidation and corrosion.

WRITE FOR ILLUSTRATED BULLETIN AC

Chromalloy corporation

169 WESTERN HIGHWAY, WEST NYACK, N. Y.
ELmwood 8-5900

CHROMIZING CORPORATION, LOS ANGELES, CALIFORNIA
PROPELLEX CHEMICAL DIVISION, EDWARDSVILLE, ILLINOIS
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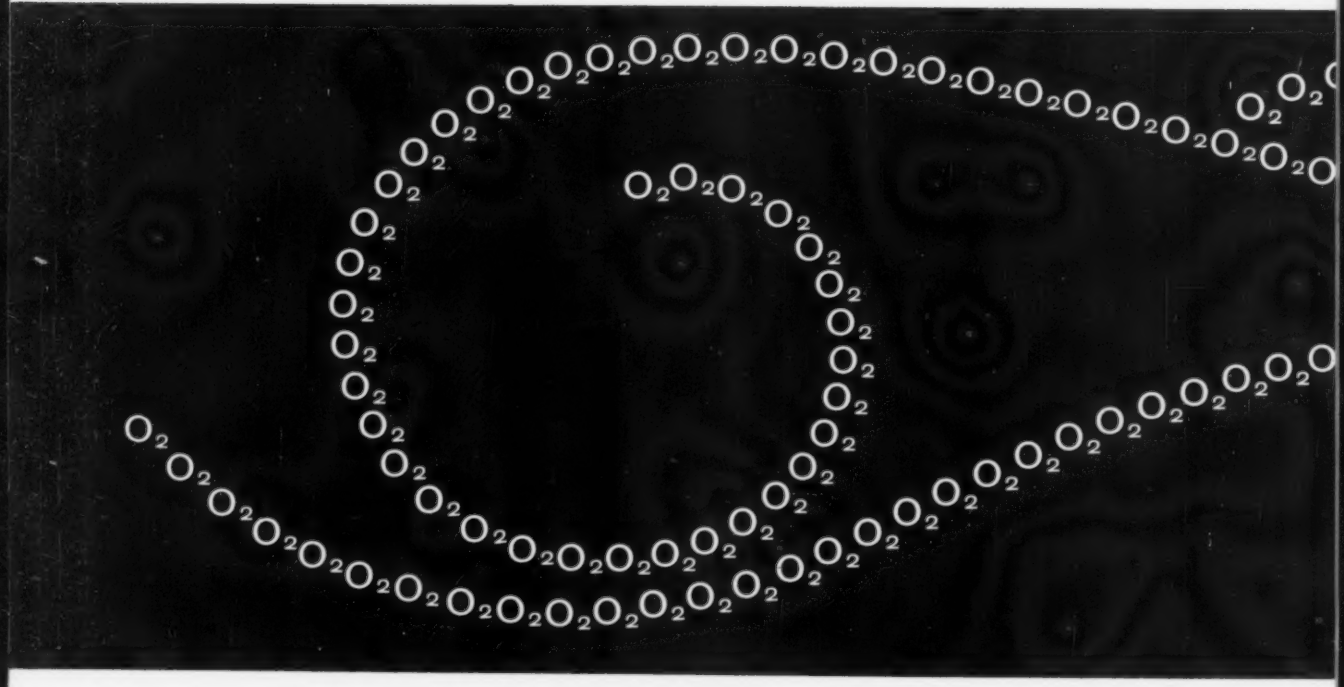
ELYRIA FOUNDRY DIVISION, ELYRIA, OHIO. Quality gray iron castings.
SINTERCAST DIVISION, YONKERS, N. Y. Machinable carbides & nuclear materials.

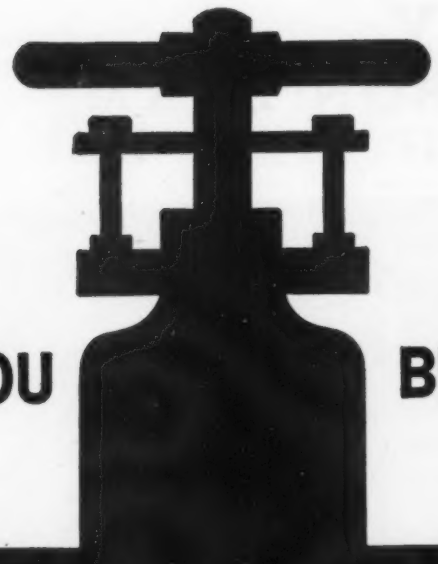
Circle 1543 on Page 48-B

O_2

OXYGEN FOR STEEL IS ALWAYS ON TAP WHEN



Oxygen piped from a plant we build and operate, on or adjacent to your site, is backed by 45 years of experience in air separation. We have the resources and sound engineering ability to keep your



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oxygen flowing even if your needs increase.
For the full oxygen story, contact Airco.

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A DIVISION OF AIR REDUCTION COMPANY, INCORPORATED, 150 EAST 42ND STREET, NEW YORK 17, N. Y.
REPRESENTED ON THE WEST COAST BY AIR REDUCTION PACIFIC COMPANY

Circle 1544 on Page 48-B

SCIAKY...
FIRST IN ELECTRON BEAM WELDING

Advanced Sciaky Design Combines Research and Production Capabilities into One Machine

If *you're* interested in electron beam welding, here's why you should investigate Sciaky machines:

SCIAKY ELECTRON GUN DESIGN...

Simple, rugged and compact! Exceptional electron optics produce beam density previously possible *only* with accelerating potentials as high as 100,000 v. The Sciaky gun, entirely contained within the atmosphere of the welding chamber, will operate in any angular position. *Both* gun and fixture can be moved to any position within the chamber while welding. Advanced focusing design results in welds with 12 to 1 depth to width characteristics.

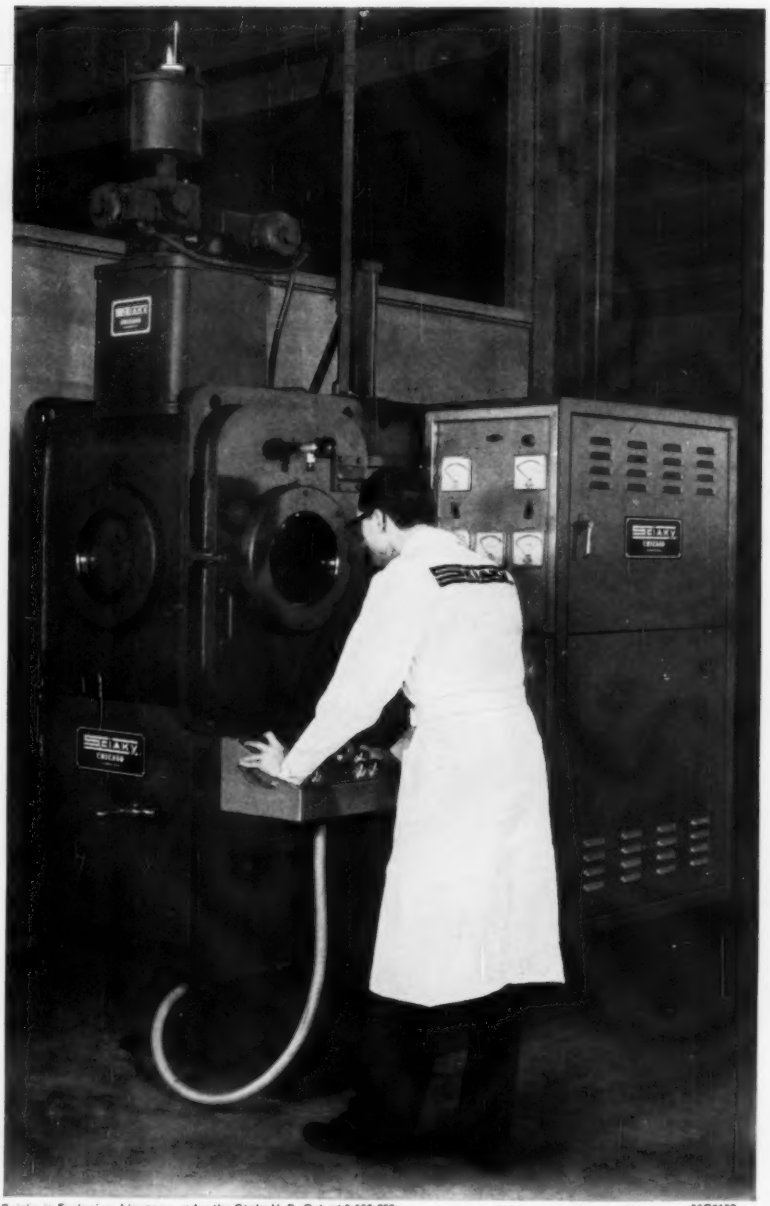
SCIAKY PUMPING SYSTEM...

Fast and efficient! Depending on chamber, only 3 to 10 minutes are needed to evacuate chamber to welding pressure. Pumping sequence is *completely* automatic with built-in safety devices.

SCIAKY SAFETY...

Unmatched! Low voltage (30,000 v. maximum) and highly refined chamber design eliminates x-ray hazards, which are a severe problem with higher voltage equipment. No costly shielding is needed.

Call or write for details of these and other Sciaky machine features. Regardless of your specific area of interest, you'll find Sciaky's combination of extensive welding experience and advanced electron beam technology to be helpful.



Sciaky is Exclusive Licensee under the Stohr U. S. Patent 2,932,720 60C6102

You can learn more about Sciaky Electron Beam Welding, fully automatic TIG and MIG Welding with modular or building block concept, and the newest in Bench Welding at the

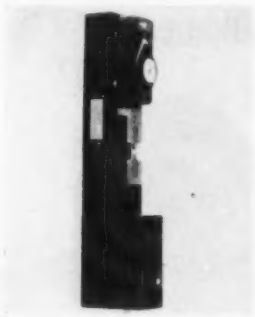
A.W.S. Welding Show, New York Coliseum, April 18, 19, 20,
Booth 729

SCIAKY BROS., INC., 4940 WEST 67th STREET, CHICAGO 38, ILLINOIS • PORTSMOUTH 7-5600

Circle 1545 on Page 48-B

Inspection and Control Equipment

Portable Tensile Tester



Up to 500 lb. force can be applied by the "Series TJ" portable tensile tester. Wire, strip or small bonded parts can be tested rapidly and accurately (½% of full-scale) on the unit. To operate, simply insert a sample in the grips and start the air motor. At failure, a force gage holds final dial reading. Maximum jaw opening is ¼ in. and maximum travel is 2 in. The rate of pull can be adjusted within limits acceptable for most production requirements. Seven models have maximum capacities from 20 to 500 lb. *Hunter Spring Co.*

For information circle No. 1296 on card, p. 48B

Gas Atmosphere Controller

The "Model 30D" automatically records and controls dew point of protective gas atmospheres used in heat treating, brazing and sintering operations. Oxidation and carbon potentials of atmospheres can also be controlled. The sensing unit is a relative humidity device, calibrated in °F. dew point (−10 to +70° F.). This sensing arrangement eliminates condensation and evaporation of water vapor in the gas sample, does away with the refrigeration unit, and reduces maintenance. *Barber-Colman Co.*

For further information circle No. 1297 on literature request card, p. 48B

Ultrasonic Testing Unit

Applications for the "Model 424D Immerscope" include nondestructive testing of plate, ingot, pipe, forgings, castings, rolled shapes, and honeycomb sections. Testing is not limited to metallic objects; other reasonably elastic materials such as glass, hard rubber, and some ceramics can also be inspected. New features on the instrument which increase its range of usefulness include a high-speed flaw alarm circuit, facilities for high-sensitivity high-resolution contact testing, variable pulse repetition rate, and a video-delay circuit. *Princeton Div., Curtiss-Wright Corp.*

For further information circle No. 1298 on card

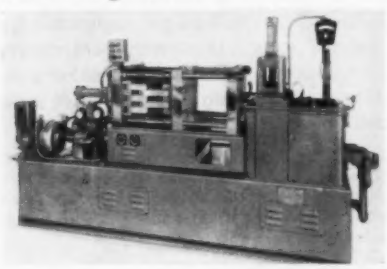
Production and Casting Equipment

M-G Power Supply For Induction Melting

For high-frequency induction heating and melting, *Inductotherm Corp.* is offering a 15 kw. "Inducto Integral 15" control unit. The unit can do the work of a 20-kw. spark-gap converter for low-volume foundry production and laboratory applications. The equipment offers lower maintenance, more efficient power utilization, and greater reliability. Heating coils operate at a constant 220 or 440 v., compared to 20,000 v. peaks with spark-gap units. This reduces arcing by 99% and allows vacuum melting.

For further information circle No. 1299 on literature request card, p. 48B

Die Casting Machine



The *American Die Casting Machinery Co.* has doubled production on a "Model 150Z" 150-ton machine. A new hydraulic pump delivers 21.8 gal. per min., making the unit one of the fastest acting machines of its size. It will operate at 1300 cycles per hr. An improved die interlock protects operator from molten metal.

For further information circle No. 1300

Ed Johnson, Furnace Application Engineer, talks about

SINTERING STAINLESS

Whether you're working with cermets, ceramics, refractory metals, or stainless steel powder compacts, Hayes has the *right* furnace and the *right* atmosphere to give you best results at lowest cost.

PRECISE SINTERING TEMPERATURES are important for effective bonding of compacts. The Hayes Type M-Y High-Temperature Furnace provides the exact, uniform heating required — has straight-through design for easy operation.

ECONOMICAL, TOO, the Hayes Type M-Y furnace needs only modest power input for temperatures to 3300°F with Moly elements. It can be used with reducing atmospheres for close control research or full-scale production, and is available with metallic or ceramic superhearths.

HIGH-SPEED HEATING and cooling cycles mean big production with the Hayes Model HT/HV Vacuum Furnace. A full-production size vacuum furnace, this Hayes unit is cold-wall designed for compactness as well as operating comfort. Heat-up to 3000°F range and over in minutes, with low voltage elements. High vacuum to 0.1 micron . . . low leak rate.

THE RIGHT ATMOSPHERE is available from the complete Hayes line —ammonia dissociators, endo and exo generators, nitrogen and forming gas generators, gas dryers — all designed for controlled, dependable operation.

WHATEVER YOUR SINTERING PROBLEM — for production, high temperature or research sintering, Hayes know-how and equipment can supply you with a Results Guaranteed answer . . . tested in our lab on shop-scale equipment, and proved by scores of similar installations in industry. Write for bulletins on Hayes sintering furnaces. C. I. Hayes, Inc., 802 Wellington Ave., Cranston 10, R.I.

C. I. HAYES, INC.

Established 1905

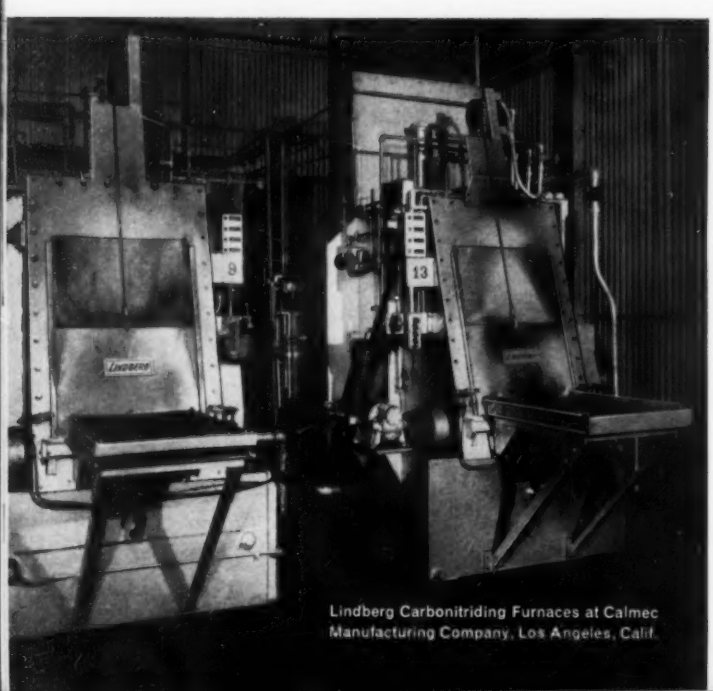
It pays to see Hayes for metallurgical guidance, lab. facilities, furnaces, atmosphere generators, gas and liquid dryers, pHayes-master (TM) control units.

Circle 1546 on Page 48-B

J. F. McINTYRE tells why CALMEC always looks to Lindberg for heat treating equipment

Left, S. E. Summers, Chief Design Engineer and at right, J. F. McIntyre, Executive Vice-President, Calmec Manufacturing Company, Los Angeles. In the Middle, J. E. Krickl, Western Sales Manager, Lindberg Engineering Company.

"When we have heat treating problems we like to get the Lindberg man right in the middle of them. We know Lindberg men are heat treating experts and the best source we have for advice on the most practical and efficient equipment to satisfy any heat treating requirement. As a result we've bought lots of Lindberg equipment in the past few years. We like it and the fact that we are continuing to buy it proves that the Lindberg man's advice has been sound."



Lindberg Carbonitriding Furnaces at Calmec Manufacturing Company, Los Angeles, Calif.

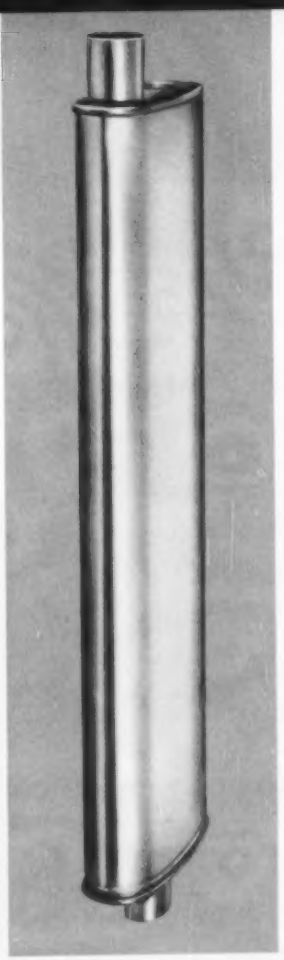
Mr. McIntyre has certainly backed up the above words with deeds. Over the past few years, Calmec, a leading manufacturer of precision tools, parts and missile system components, has installed twelve electrically heated furnaces, six gas-fired furnaces and four atmosphere generators—all Lindberg! And we hope there are more to come. If you have any product or process in the metal or ceramic field requiring the application of heat it would be a good idea to get the Lindberg man in the middle right away. You can depend on his experienced help and Lindberg's engineering and design know-how to provide exactly the right equipment for your need. It's easy! Just get in touch with your Lindberg Field Engineer (see your classified phone book) or write us direct. Lindberg Engineering Company, 2448 West Hubbard Street, Chicago 12, Illinois.

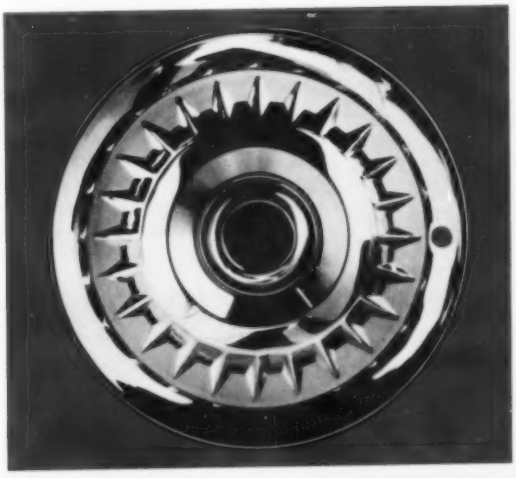
Los Angeles plant: 11937 S. Regentview Avenue, Downey, California. In Canada: Birlefco-Lindberg Ltd., 15 Pelham Ave., Toronto 9, Ont. Also, Lindberg plants in Argentina, Australia, England, France, Italy, Japan, South Africa, Spain, Switzerland and West Germany.

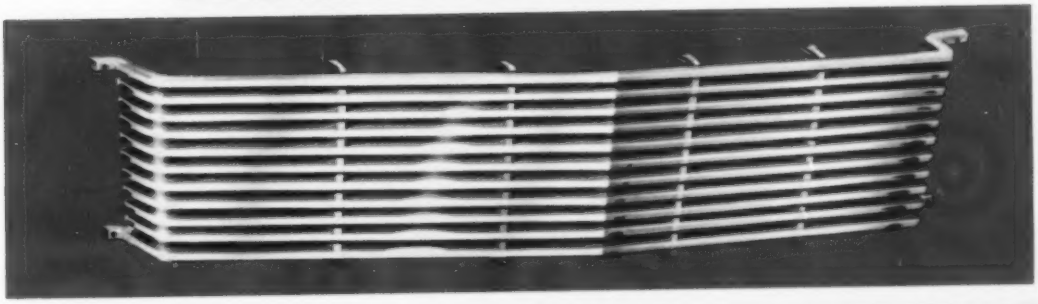
Circle 1547 on Page 48-B

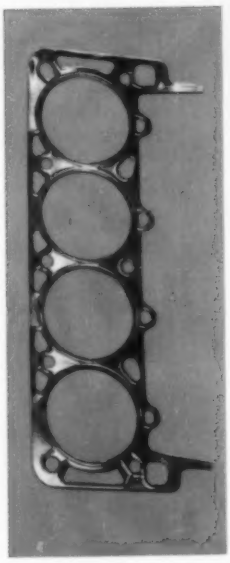
LINDBERG
heat for industry

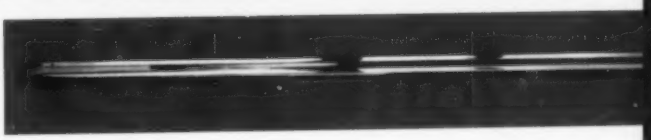
Automotive Horizons and Allegheny Stainless...











STAINLESS...a growing force in today's automotive design

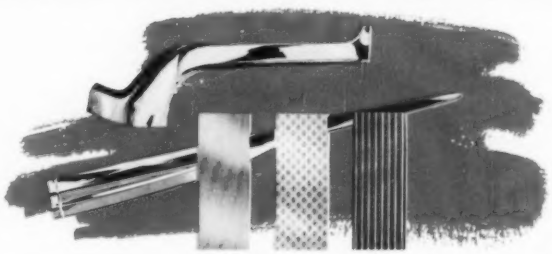
The continued improvement in stainless steels and the increased demand of today's motorists for attractively styled automobiles that stay attractive have combined to throw open the door to more and more stainless automotive applications. And longer warranties are pushing the trend to stainless. Here are some of the places you're most likely to find Allegheny Stainless on cars today... or maybe tomorrow.

Mufflers and Tailpipes

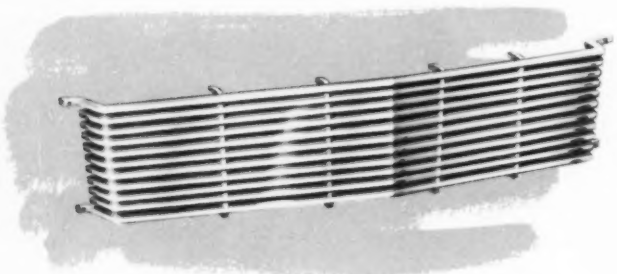
It's long been admitted by automotive people that a car shouldn't have one of its components operating in a hot, highly-corrosive environment without real corrosion resistance built into that part. But it's been a cost problem. Allegheny Ludlum's answer to the muffler problem is MF-1, a special, economical, ferritic stainless steel with good formability and corrosion resistance. Mufflers made from MF-1 have corrosion resistance built in. The stainless is solid. There will be mufflers made entirely from MF-1; others with MF-1 in the corrosion-susceptible internal wraps and baffles only. In either case, this corrosion resistance won't chip, peel, or burn off.

Trim

Nothing enhances the beautiful lines of an automobile like sparkling brightwork, and nothing is a bigger chore to care for if it begins to spot and pit, rust or peel. With Allegheny Stainless trim, the original beauty is a beauty forever, stainless clear through and as corrosion resistant in its old age as the day it came off the line. Highly formable, gleaming bright, protective and dent resistant...stainless steel.



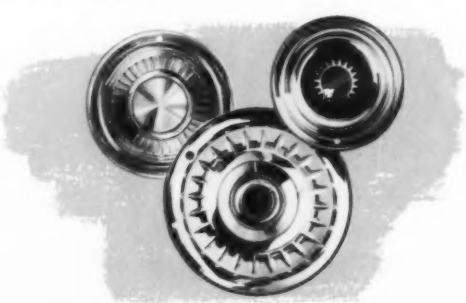
Grilles



Nothing establishes the appearance of a car as much as the "expression on its face"...its front end-grille design. And nothing has more to contribute to the beauty, prestige, and crisp styling of the grille design than stainless steel. Allegheny Stainless in bar form, tubing, strip or patterned sheet lends itself to economical fabrication techniques...roll forming, expanded metal, spot welding...all important in any fabrication with as much resultant waste as present grille forming techniques. Automotive engineers, using some of these newer processes, are re-evaluating stainless.

Hubcaps and Wheel Covers

Wheel covers and hubcaps demand a variety of metal characteristics and some are almost mutually incompatible...springiness, formability, dent resistance, brightness, corrosion resistance, scratch resistance, dimensional stability, stiffness...and more. Only one metal can come close to meeting all these requirements...stainless steel.



STAINLESS...both on and over the automotive horizon

More and more stainless steel will appear on the cars of tomorrow. Everything points to it...today's conditions require it, so will tomorrow's. There's a definite trend to longer warranty periods. Competition will probably cause these warranties to be extended, and extended yet again. Parts simply must last longer to make these warranties possible.

There's also a trend toward less owner-maintenance, such as sealed lubrication systems, sealed engine coolant and automatic air conditioning systems, self-adjusting brakes, and the like. Design features such as these will continue. Again, competition will probably force the extension of such systems, and their inevitable elaboration.

Both trends lead to increased use of Allegheny Stainless. When parts just have to stand up in warranty, the call is for stainless. And when less owner-maintenance develops, the corrosion resistance and foolproof characteristics of stainless begin to pay off. Such hidden applications as fuel tanks, floor pans, surge tanks, radiator systems, etc., are already receiving a good, hard look from engineers as future stainless applications.

Other requirements are advanced by design problems and improvements in automotive interiors. Gleaming, durable stainless steel makes a sales feature of the constant, close-up scrutiny of even the most discriminating auto passenger. It stands up under constant handling, scuffing and lack of polishing and provides the modern automotive interior with the ornamental brilliance that is uniquely stainless.

Characteristic of stainless, as well, is its remarkable ability to withstand elevated temperatures for long periods of time, and to resist corrosive environments under such conditions. As early developmental work has shown, this admirably fits it for service on the numerous anti-smog devices now vying for official recognition. With service temperatures as high as 1800 F, with lead oxide, sulfur, catalysts, and other chemical corrosion a factor, no other material can be actively considered aside from a stainless, heat-resisting steel.

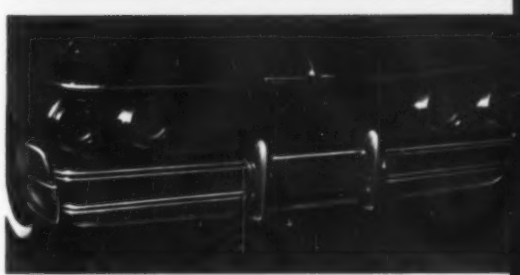
These are just a few thoughts on how Allegheny Stainless and the automotive designers will be working for motoring enjoyment...tomorrow or the next day.

Bumpers

Possibly the most exciting design possibilities involve the front and rear of the modern automobile and the need for bumpers. Designers are faced with the task of integrating a massive section of metal into an overall design concept. Stainless steel can play a very great part in this effort, from both the esthetic and structural standpoints.

One interesting bumper technique is the fabricated bar bumper of stainless steel. Solid stainless bars offer an unmatched combination of beauty and strength, are easily formed, and may be worked into a variety of front-end designs featuring floating grilles and fabricated bumper guards. Stainless bars are repairable, by straightening, welding, buffing...all relatively simple operations.

Or, the protection and beauty of stainless steel may be obtained in a bumper with a metallurgically-bonded stainless cladding over the baser, underlying metal. Cladding offers the same exterior corrosion resistance and durable beauty as solid stainless designs. It won't scrape, peel, or rust. And, for maximum impact strength, and equal protection with lighter cross sections, some of the high strength stainless grades offer most interesting avenues for exploration.



Interiors

The hidden Value of Stainless in Automotive Design...

Ask a housewife about this strong and handsome metal ...about its useful life, its strength, its corrosion resistance. She'll be able to tell you...she lives with it daily and sees it everywhere. She knows its beauty and prestige-building appeal, its dollar-value economy.

But aside from these obvious advantages, stainless steel has hidden values for those who really know it well, an added desirability based on reasons both functional and esthetic...practical and personal.

IN DESIGN

...to designers, stainless steel has a highly utilitarian character. Designers feel better about working with its honest nobility. They prefer its reliability, its mathematical predictability, its strength, the look and feel of it, and its uniquely masculine character. It's a designer's metal.

IN STYLING

...to stylists, the rich luster and high prestige of stainless steel provide an irresistible creative challenge. They are intrigued by the limitless possibilities offered by its variety of textured surfaces and finishes, its ease of forming, bending, shaping. It's an expressive metal... a stylist's metal.

IN MARKETING

...salesmen and marketing men know the value of stainless in automotive design. They know a customer's reaction to it. They know the universal appeal of stainless, the built-in customer acceptance based on its unqualified success in kitchen and other home appliances, in sporting goods, jewelry, and cutlery. It helps sell. It's a salesman's metal...a marketing metal.

ALLEGHENY LUDLUM STEEL CORPORATION

General Headquarters: Oliver Building, Pittsburgh 22, Pa.

EVERY FORM OF STAINLESS . . . EVERY HELP IN USING IT

3001

Litho in U.S.A.

Test salt bath neutrality quicker with a razor blade

Liquid salt baths have long been recognized for their stability, freedom from decarb and the protection they afford the surface being treated.

Regardless of the inherent stability of molten salts, however, they do occasionally become contaminated which may result in decarburization. When this happens the metallurgist can use a simple homespun method to determine the bath's neutrality.

The hard way is a metallographic check, which involves cleaning, sectioning, mounting, polishing, etching and examining a specimen under the microscope. This is costly and time-consuming.

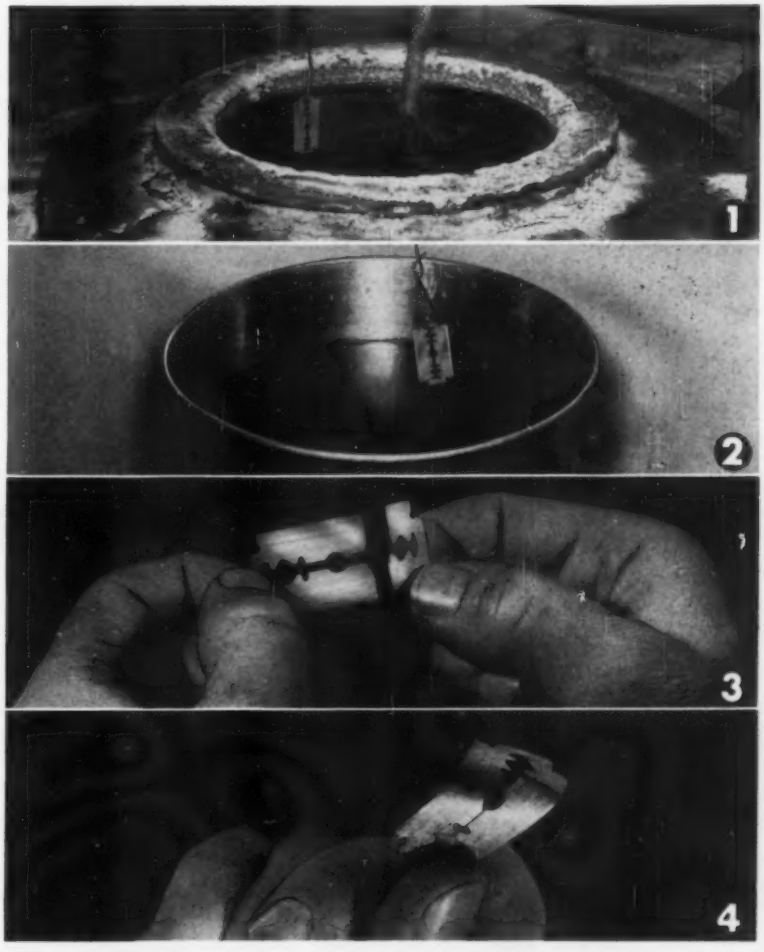
The simple way requires only an old razor blade, the double-edge type, and not one made of austenitic stainless steel. This method has been found very practical and accurate.

The blade is hung on a wire and dipped into the hardening bath of molten salt (photo no. 1), leaving it immersed for about the same time as the work being regularly heated there, and at the same temperature. Then it is quenched rapidly in water (photo no. 2).

Now for the simple bending and breaking test. Hold the blade in two hands and bend it. If it breaks with a brittle fracture (photo no. 3), the bath is neutral—no tendency to decarb. But if it bends before breaking (photo no. 4), this evidence of ductility indicates that the bath is decarburizing.

The ductility or absence of ductility indicates the condition of the salt bath. If the blade is ductile and can be bent 90° or 180° before fracturing, the steel is partially or completely decarburized. If the blade is not ductile but breaks with a brittle fracture, the bath is in good condition and work may be processed satisfactorily.

This simple test saves much time and the need for expensive metallographic equipment. It is not 100% sure, but our metallurgical friends find it very helpful for a quick and revealing test of the effect of molten salt on metal.



Heat treaters have come to expect the best from Houghton. And along with product purity, speedy delivery and well packaged materials "the best" includes assistance and cost-saving "hints" such as the razor blade test. Houghton makes and services salts for carburizing, hardening, annealing, tempering, quenching and nitriding. For the Salt Bath Catalog, write E. F. Houghton & Co., 303 W. Lehigh Avenue, Philadelphia 33, Pa.

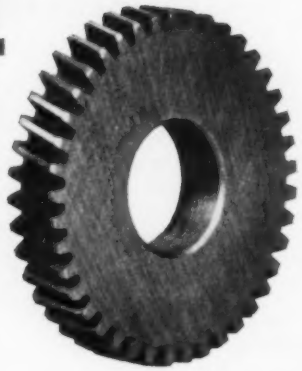
Houghton

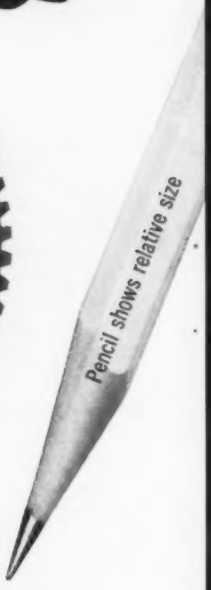
INDUSTRY'S PARTNER IN PRODUCTION

Circle 1548 on Page 48-S

CINCINNATI®

Advanced Heat Engineering





combines 4 operations into 1...
creates abundant time-cost savings

A CINCINNATI INDUCTRON® Heating Machine, with ingenious tooling, accomplishes the following automatic operations on motor armature shafts and gears used in portable power tools:

Harden gear teeth
Press shaft into gear.
Shrink-fit gear to shaft.
Draw gear teeth to Rc 40-45.
Floor-to-floor time: 9 seconds
Production rate: 400 assemblies per hr. (gross).

Previously, the gear was heated in an induction heater while the operator manually pressed the shaft into the gear with a leverage press. After quenching, the assembly was drawn in a gas-fired furnace for 1 hour at 750° F.

From CINCINNATI ADVANCED HEAT ENGINEERING, you receive the technological know-how gained by research and experience in applying heat as a tool . . . the selection from modern flame or induction heating machines to give you the most efficient and economical method . . . skillfully applied work-handling systems of a high calibre from the world's largest builder of machine tools.

CINCINNATI 30 kw Radio Frequency INDUCTRON showing work-handling mechanism to process the gear-armature shaft assembly shown. Cincinnati Meta-Dynamics Division also builds Motor-Generator INDUCTRON and FLAMATIC® flame heating machines.

For hardening • heating for forging • shrink fitting • brazing • soldering • annealing • tin re-flow • bonding • wherever heat is used as a tool • benefit from Cincinnati Advanced Heat Engineering.

META-DYNAMICS DIVISION

CINCINNATI

THE CINCINNATI MILLING MACHINE CO.

Cincinnati 9, Ohio

Circle 1549 on Page 48-B

NEW LITERATURE

Ferrous Metals

1302. Alloy Steels
Booklet "Quick Facts About Alloy Steels" from *Bethlehem Steel Co.* . . . An elementary presentation of metallurgical knowledge of steel.

1303. Precision Ground Steel
Illustrated file folder cites the advantages of using precision ground steel. Chemical composition and typical applications for three new grades are included. *Vanadium-Alloys Steel Co.*

1304. Comparison Chart
Peter A. Frasse & Co., Inc. announces the availablity of a wall chart showing chemical analysis requirements for military army, navy, aeronautical, and federal alloy steel specifications. Also listed are specified forms and nearest corresponding S.A.E., A.I.S.I., and A.M.S. numbers.

1305. Bright-Annealed Stainless
Sharon Steel Corp. has issued 4-p. brochure on bright annealed stainless steel for automotive trim applications.

1306. Spring Steel
Brochure from *Sandvik Steel, Inc.* summarizes data on various cold rolled or hardened and tempered strip steels for spring applications.

1307. Cold Finished Bars
Folders from *Bliss & Laughlin* present data on complete line of high-strength cold finished steel bars for maximum machinability and high strength.

1308. Leaded Steels
Catalog from *Aristoloy Steels Div.* details the advantages of working with leaded steels—reduced machining time and extended tool life.

1309. Stainless Steels
Stainless steels can give your product designs many special advantages. Catalog "Armco Stainless Steels" describes more than 50 grades. *Armco Steel Corp.*

1310. Vacuum-Melted Steels
Vacuum-melted alloy and specialty steels are produced in 18 to 32 in. diameter ingots weighing 4000 to 20,000 lb. Details from *Republic Steel Corp.*

Nonferrous Metals

1311. Rare-Earths
Lindsay Chemical Div. has published a bulletin entitled "Rare Earth and Yttrium Metals."

1312. Rare-Earth Metals
Brochure from *Lunex Co.* gives information on high-purity rare-earth metals—praesodymium, yttrium, gadolinium, neodymium.

1313. Beta Titanium Alloy
32-p. manual on "Properties of Ti-13V-11Cr-3Al" includes data on metallurgy, design, and fabrication. *Titanium Metals Corp. of America.*

1301. Machining of Aluminum

Kaiser Aluminum and Chemical Corp. has published a 98-p. booklet on machining aluminum with automatic screw machines. Contents include a description of automatic screw machines, as

well as chapters on tooling, speeds and feeds, cutting fluids, and availability of aluminum mill products. A chapter which reviews various machining troubles and suggests corrective action is particularly good.

1314. Molybdenum Information
Folder gives complete listing of all information available from *Climax Molybdenum Co.* on molybdenum-base alloys and steels, irons, and nonferrous alloys containing "moly."

1315. Aluminum Extrusions
Aluminium Limited Sales, Inc. has published a list of independent aluminum extruders who can furnish you with a wide range of shapes to meet your most exacting requirements.

1316. Uses for Tin
16-p. brochure from the *Malayan Tin Bureau* contains information on the latest uses of tin in U.S. industry.

1317. Nonferrous Products
16-p. buyers directory of products and services includes information on aluminum, brass, bronze, copper, nickel silver, rhenium, stainless steel and zirconium. *Chase Brass & Copper Co.*

1318. Copper Alloys
Special Alloys Kit No. 13 gives the facts on a range of alloys having high hardness and wear properties, excellent electrical conductivity, or free-machining properties. *Mueller Brass Co.*

1319. Leaded Copper
Anaconda-American Brass Co. has published data on "Leaded Copper-126", which has good electrical conductivity (98% I.A.C.S.) and a relative machinability rating of 80 compared to 20 for electrolytic tough-pitch copper.

1320. Degassing of Aluminum
4-p. bulletin discusses problem of gas porosity in aluminum castings and outlines specifications for "Foseco Degaser", a metallurgical compound which scavenges hydrogen and non-metallic inclusions. *Foundry Services, Inc.*

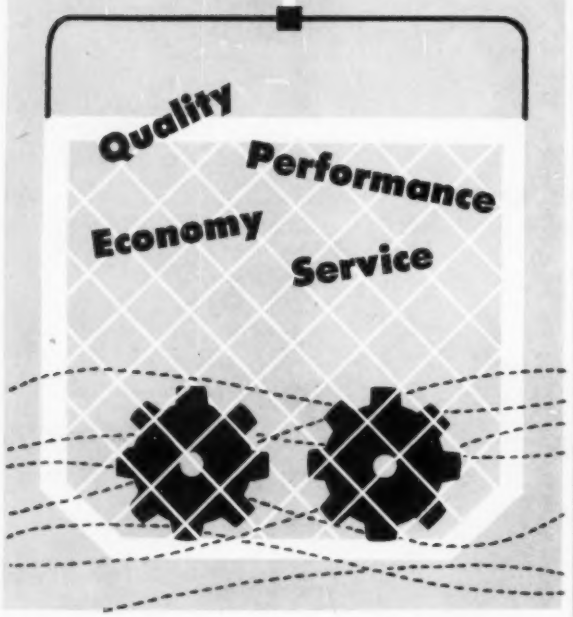
1321. Nickel Alloys
For a guide to information about nickel, its alloys and industrial applications, send for catalog of publications. List "A" from *The International Nickel Co.*

1322. Aluminum Mill Products
Strahs Aluminum Co. Inc. is offering 160-p. catalog-handbook listing complete line of aluminum mill products available from stock. Technical information and engineering data also included.

1323. Lanthanum through Lutetium
Booklet "Rare Earth and Yttrium Metals" discusses metallurgical, electronic, semiconductor and research applications for these products. *American Potash & Chemical Corp.*

To request any item listed, circle appropriate number on Reply Card, p. 48-B

HEATBATH SALT BATHS FOR



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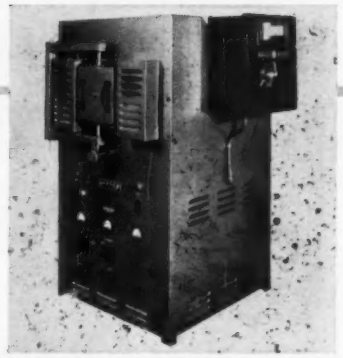
HEATBATH CORPORATION

SPRINGFIELD 1, MASSACHUSETTS
or 701 North Sangamon St., Chicago 22, Ill.
39 Years of Service to the Heat Treating and Metal Finishing Industry

Circle 1550 on Page 48-B

Variety of applications with pinpoint accuracy



HARROP ELECTRIC FURNACES with Non-Metallic Resistor

Versatile, rugged design gives Harrop NMR Series furnaces great latitude in the application of heat to materials ranging from ceramics and ferrites to metals and cermets. Controls heat and measures temperatures accurately under continuous operation to 2820° F., and higher for intermittent operation. Oversize components and refractory linings prevent accidental lining damage. Six standard models range in setting space from 7 x 9 x 9 inches to 36 x 45 x 41 inches. Available in four cabinet forms and furnished with instrumentation to meet any specific requirements. Two models are equipped with mechanical or hydraulic elevator.

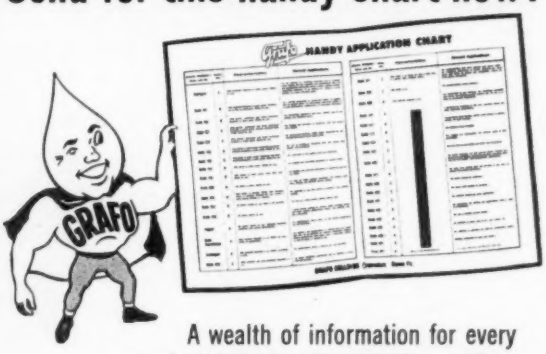
The NMR Series is typical of all Harrop furnaces . . . designed to meet specific requirements but with scope to meet a variety of firing needs. Harrop experience is available to help find solutions to any problem involving controlled application of heat or the accurate measurement of temperature. Harrop experience cuts across the full range of engineering skills to provide detailed recommendations based on complete analysis of materials, range, control and objective. For prompt and interested evaluation of any firing problem, theoretical or practical, write Dr. Robert A. Schoenlaub, Director of Research, 3470 E. Fifth Ave., Columbus 19, Ohio.

HARROP PRECISION FURNACE CO.

(A Division of Harrop Ceramic Service Co.)

Circle 1562 on Page 48-B

Send for this handy chart now!



A wealth of information for every user of lubricants and protective coatings

There are so many uses for GRAFO Colloidal Graphite in Oil, Water and Alcohol Dispersions that you'll find this new handy Application Chart indispensable in selecting the right GRAFO products for your needs!

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Circle 1563 on Page 48-B

Heat and Corrosion Resistant Materials

1324. Corrosion-Resistant Alloys

Haynes Stellite Co. is offering a 104-p. book which discusses "Haynes" corrosion-resistant alloys, their properties, forms, and the corrosives they will resist.

1325. Thermal Fatigue

The *Electro-Alloys Div.* has published "The Mechanism of Thermal Fatigue" by H. S. Avery.

1326. René 41

G.E.'s Metallurgical Products Dept. has data on René 41; unique properties make it ideal for use in everything from jets to machine components.

1327. High-Temperature Alloys

Seventeen "Haynes" alloys are compared against each other in the areas of physical, mechanical and chemical properties and stress-rupture data. 20-p. booklet from *Haynes Stellite Co.*

1328. Ceramic-to-Metal Seals

Flyer from *Wilbur B. Driver Co.* gives data on "Ceramiseal," an iron-nickel-cobalt alloy for ceramic-to-metal sealing applications.

1329. Service at 4600°F.

Want the full story on molybdenum products for 4600° F. applications? Check the Chemical & Metallurgical Div., *Sylvania Electric Products.*

1330. Tungsten and Moly

General Electric Co. has information on pressed and sintered molybdenum and tungsten, available as forging billets, sheet slabs, tubes, or consumable electrodes for vacuum arc melting.

1331. Iron Powder

Products made with iron powders provide design flexibility, reduce production costs and can be manufactured to closer tolerances. Information from *Alan Wood Steel Co.*

1332. Forged Rings

Weld-free rings are forged from cylindrical castings instead of rolled from bar stock and welded. Available in René 41 or iron, nickel, and nickel-cobalt alloys. *Cannon-Muskegon Corp.*

1333. Glassed-Metal Products

16-p. Bulletin 987 describes glassed-metal pipe, valves and fittings for installations that require resistance to corrosion or processes than cannot tolerate contamination of product. *Pfaudler Co.*

1334. Service at 2300° F.

Electro-Alloys Div. has issued pamphlet containing data on "Supertherm", a 26% chromium, 35% nickel alloy for service in 1800 to 2300° F. range.

1335. High-Temperature Alloy

16-p. booklet from *Haynes Stellite Co.* presents the facts on "Haynes Alloy No. 56", an alloy of chromium, nickel, cobalt and iron which possess excellent strength and oxidation resistance at elevated temperatures.

Tool Materials

1337. Forging Lubricant

Bulletin 426 shows how production costs on aluminum alloy forgings can be lowered by selecting the proper dispersion lubricant. *Acheson Colloids Co.*

1338. Grinding Wheel Specifications

A copy of the new publication "American Standard Specifications for Standard Shapes and Sizes of Grinding Wheels, B74.2-1960" may be obtained from the *Grinding Wheel Institute.*

1339. Machining Compound

Five times the film strength of straight oils—this is the claim for an all-purpose machining compound "No. 576", a petrochemical derivative. Literature available from *Baker-Gubbins Co.*

1340. Saw Blades

Catalog C-85 gives the complete story on "Marvel" hacksaws, bandsaws, and blades for both. *Armstrong-Blum Mfg. Co.*

1341. Machining Lubricant

E. F. Houghton & Co. will send application data on "Hocut 237", a fortified chemical coolant which does a double job of improving quality and reducing machining costs.

1342. Rotary Slitters

The Yoder Co. has released a manual on slitting operations and equipment. Methods, time studies, operating cycles, materials handling, and full specifications are presented.

1343. Die Blocks

Bulletin 300 details the advantages—increased ductility and toughness—of vacuum degassing the steel which goes into die blocks and hot work toolsteels. *A. Finkl & Sons Co.*

1344. Drawing Lubricant

Bulletin 26 describes "Fleximet S", a multipurpose lubricant for dry drawing and hot dip dry-film coatings. *Swift & Co.*

1345. Steels for Tools

The *Uddeholm Co. of America* will provide you with information on hot-work toolsteels for standard or severe applications.

1346. Semi-Automatic Forging

The "Ceco Blowmatic" program controller pre-selects pattern of long and short strokes for semi-automatic forging on the "Ceco-Drop" gravity drop hammer. *Chambersburg Engineering Co.*

1347. Lubricant Coating

Characteristics of "Molykote PVE", a bonded-lubricant coating for ferrous bearing surfaces and for cutting tools, is described in data sheet published by *Alpha-Molykote Corp.*

1348. Abrasive Discs

4-p. brochure tells about a fiber-backed adhesive disc for light grinding operations where little or no dressing action is involved. *Carborundum Co.*

1349. Hot Work Toolsteel

Data Sheet 16 summarizes properties on "*Heppenstall* T73" a low-carbon, medium-tungsten hot work steel with high red hardness, intended for forging and extrusion dies in brass mills.

1350. Steel-Bonded Carbides

12-p. manual describes "Ferro-Tic C" a machinable and hardenable steel-bonded carbide tool material. *Sintercast Div., Chromalloy Corp.*

1351. Die Release Agents

E. F. Houghton & Co. will send data sheets on "Mouldlubric LCS and 3326" for aluminum die- and permanent-mold casting operations.

1352. "Disperser"

Periodical issued by *Acheson Colloids Co.* relates how well known firms overcome lubrication problems in extreme heat and achieve a better finish on castings.

Industrial Heating

1353. Heat Treating Baskets

Whatever the part, large or small, there is a basket, tray, fixture, or container to handle it better through heat treating and quenching. Catalog 61, *Stanwood Corp.*

1354. Gantry Furnace

12-p. color catalog reviews line of standard, modified, and special furnaces, including world's largest gantry furnace facility. *Pacific Scientific Co.*

1355. Oil Coolers

Bell & Gossett Co. has issued a combined catalog and selection manual on a "Hydro-Flo" oil cooler. These units combine coolers, motors, strainers and all controls into an easily installed package.

1356. Infrared Ovens

8-p. folder on fused quartz radiant ovens has been released by *Cleveland Process Corp.* On-the-job applications and performance data on equipment are included.

1357. Induction Heating

8-p. pamphlet on induction heating and melting equipment is available from *Ajax Magnethermic Corp.* Subjects include low and high frequency melting, and vacuum melting and degassing.

1358. Gas Burners

Combustion Div. of Eclipse Fuel Engineering Co. has issued 14-p. Bulletin No. H-1 illustrating eight gas-fired burners with maximum firing capacities from 10,000 to 2,750,000 Btu. per hr.

1359. Thermocouple Catalog

60-p. booklet contains complete specifications on thermocouples, pressure probes and allied components. *Advanced Dynamics, Inc.*

1360. Gantry Furnace

Literature from *Commercial Steel Treating Corp.* discusses gantry-type heat treating furnace for clean hardening, stress relieving, brazing, gas carburizing, normalizing, precipitation hardening or cycle annealing.

1361. Thermostatic Bimetal

W. M. Chace Co. has published pamphlet which contains design data on successful applications of more than 40 types of thermostatic bimetals.

1362. Temperature Crayons

"Tempilstiks" are used in determining temperatures in welding, metalworking, and heat treating. Details supplied by *Tempil Corp.*

1363. Roller Hearth Furnaces

General Electric's line of roller hearth furnaces—gas and electric—offers higher production, improved quality and lower production costs. Bulletin GED 4304.

1364. Program Controller

Bulletin F-10191 describes "Series 2000" cam-operated program controller which reproduces time-temperature cycles with "electronic link" mechanism. *Wheelco Industrial Instruments Div.*

1365. Radiant Tubes

"Wrought-Cast" radiant tube assemblies gives consistent long life because they combine a cast return bend with straight tubes made from rolled and welded plate. *General Alloys Co.*

1366. Refrigeration Systems

Data sheet and catalog give full information on *Harris Mfg. Co.* "Cascade" refrigeration sytems for low-temperature industrial uses.

1367. Sintering Furnaces

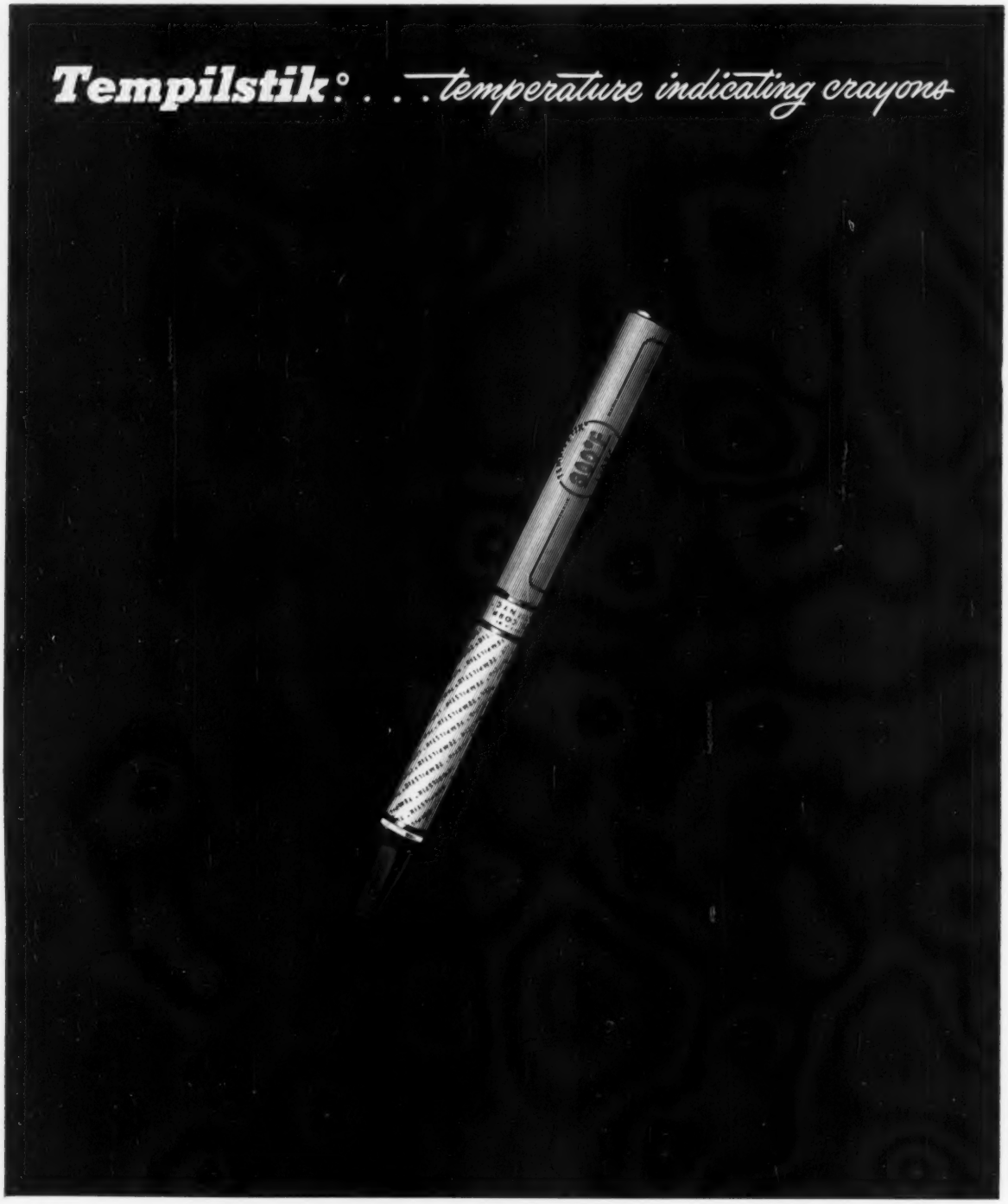
16-p. bulletin from *Electric Furnace Co.* sets forth the advantages, properties and applications of powdered metal products and discusses furnaces used in sintering operations.

1368. Shaker-Hearth Furnaces

Heat treat small parts with a shaker hearth furnace; capacities from 150 to 800 lb. per hr. *American Gas Furnace Co.* will send complete data and specifications.

To request any item listed, circle appropriate number on Reply Card, p. 48-B

Tempilstik° . . . *temperature indicating crayons*



TEMPILSTIKS° are widely used as a standard method of determining temperatures in welding procedures, metal working and heat treating, steam trap maintenance, tire-retreading, plastic forming and hundreds of other heat-dependent operations. Available in 80 different temperature ratings . . . $2.00 each. Most industrial supply houses carry Tempilstiks°. If yours is an exception, then write direct to us for further information.

Tempil° CORPORATION • 132 West 22nd St., New York 11, N. Y.

Circle 1551 on Page 48-B

1369. Thermocouple Alloys

Hoskins Mfg. Co. had published manual containing application data on wide range of Chromel-Alumel thermocouple alloys.

1370. Program Control

Information from *Leeds & Northrup* on master-slave program control which includes "Speedomax H" controllers and a master-slave programer for automatically and continuously adjusting control-point for each zone.

1371. Continuous Draw Furnace

Bulletin SC-182 describes continuous furnace and other "Power Convection" furnaces which feature high-speed high-volume air circulation. *Surface Combustion Div.*

1372. Carburizing Furnace

Bulletin SEC-9 gives the facts on the "Casemaster" furnace for continuous carbonitriding, carburizing, carbon restoration, normalizing, annealing and hardening operations. *Sunbeam Equipment Corp.*

1373. Surface Pyrometer

Catalog No. 168 describes a universal "Pyro" surface pyrometer—quick-acting and precise with easy to read 4¾ in. dial. Single and double ranges available: 0 to 300° F. and 0 to 1500° F. *Pyrometer Instrument Co. Inc.*

1374. Thermocouple Manual

56-p. thermocouple manual from *Bristol Co.* discusses thermocouple types, reproducibility, calibration, insulation and protection, and proper selection.

1375. Vacuum Furnaces

Pamphlet from *Ipsen Industries, Inc.* sets forth data on "Model VFC-300" automatic vacuum heat treating unit, which operates at one-half the cost of a hydrogen furnace.

1376. Optical Pyrometer

Brochure from *Instrument Development Laboratories, Inc.* describes "Pyro-Eye", a two-color optical pyrometer which provides automatic temperature measurement, recording and control in ranges from 750 to 2500° C.

1377. Multi-Point Controller

Data Sheet 52-16 from *Thermo Electric Co.* contains information on a multi-point controller, which controls 10 process temperatures accurately and automatically.

1378. Induction Hardening

The Ohio Crankshaft Co. will send booklet entitled "Typical Results of Tocco Induction Hardening and Heat Treating".

1379. Furnace Tubes

All-sheet construction of furnace tubes extends tube life, promotes uniform flow of gas and reduces carbon build-up. Information from *The Pressed Steel Co.*

1380. Salt Baths

A "65KW" salt bath with oil quench can be used for carburizing, brazing and hardening operations. Details in "Tips and Trends", Vol. 11, from *Ajax Electric Co.*

1381. Sintering Furnace

Brochure describes "Type M-Y" high-temperature furnace which provides exact, uniform heating required for effective bonding of cermets and other compacts. *C. I. Hayes, Inc.*

1382. Temperature Measurement

Alnor Instrument Co. will send Bulletins 2146-C and 4257 describing the "Pyrometer Model 2300" (range —40 to 200° F.) and the "Thermocon Model 4200" with eight standard ranges from 0 to 300° F. to 0 to 1600° F.

1383. Industrial Oven

Twin circulation in industrial ovens is explained in Bulletin 960. Uniform heat under full-load conditions, reduces cycle time and minimizes rejects. *Ramco Equipment Corp.*

1384. Radiation Thermometer

Pamphlet R-103 describes the "Model TD-6 Thermodot" which measures and controls temperature without contact. *Radiation Electronics Co.*

1385. Quench Tank Mixers

Mixing Equipment Co., Inc. will supply information on proper mixer and optimum tank contour design to solve your quenching problems.

1386. Temperature Indicators

Markal Co. has published literature on "Thermomelt" temperature indicating crayons. Also available in liquids and pellets for inaccessible places.

Cleaning and Finishing Equipment

1387. Electroplating Processes

24-p. Bulletin EP-102 discusses 18 electroplating processes, including three new nickel plating operations. *Hansen-Van Winkle-Munning Co.*

1388. Phosphate Coating

"Cryscoating", the conversion of a steel surface to a phosphate surface, creates a perfect base for paint adhesion. Details from *Oakite Products, Inc.*

1389. Heavy-Duty Blast Cleaning

Bulletin 705 published by *Pangborn Corp.* illustrates five heavy-duty "Roto-blast" barrels with work capacities ranging from 15 to 102 cu. ft.

1390. Nickel Alloy Plating

No other process can apply a hard, corrosion resistant nickel-alloy coating without the use of electricity. Get the facts on the "Kanigen" process from *General American Transportation Corp.*

1391. Inspection Manual

34-p. booklet covers significant factors governing inspection, properties, specifications, and purchasing of hot dip zinc coatings. *American Zinc Institute.*

1392. Anodizing Aluminum

80-p. Bulletin No. 52 presents data on uses and properties of chromium chemicals for anodizing aluminum and other metal treatments. *Solvay Process Div., Allied Chemical Corp.*

1393. Chem-Milling

16-p. brochure discusses "Metal-Etch Resist", a product which opens new chemical milling applications in weight reduction and parts manufacture. *Eastman Kodak Co.*

1394. Metallic Abrasives

Pamphlet from *Cleveland Metal Abrasive Co.* gives the facts on applications for metallic abrasives.

1395. Solvent Degreasing

Detrex Chemical Industries will send Dr. C. E. Kircher's article "How to Get the Most Out of Solvent Degreasing".

1396. Protective Coatings

Allied Research Products, Inc. has published a technical manual on "Iridite" chromate conversion coatings and "Irilac" clear protective coatings for aluminum, magnesium and zinc-plated parts.

1397. Phosphating Process

Booklet from *Turco Products, Inc.* contains phosphating reference chart; also a discussion of "Paintite" and ten other phosphating and conversion coating processes.

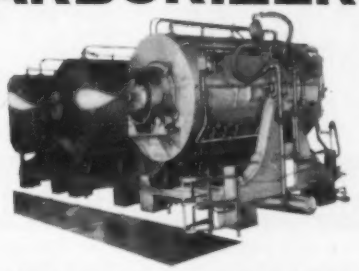
1398. Glass Shot

Microbeads Inc. will send information

Circle appropriate number on Reply Card, p. 48-B

AGF

ROTARY CARBURIZERS



AGF's Work in Motion Principle Assures Uniformity of Case!

AGF Rotary Batch Carburizers provide the most reliable method for DEEP CASE CARBURIZING and LIGHT CASE HARDENING.

Recent AGF combustion and control system improvements provide an even greater degree of temperature and product uniformity than was ever before possible.

For POSITIVE COST REDUCTION and PRODUCT IMPROVEMENT, investigate the NEW Improved AGF Rotary Carburizers.

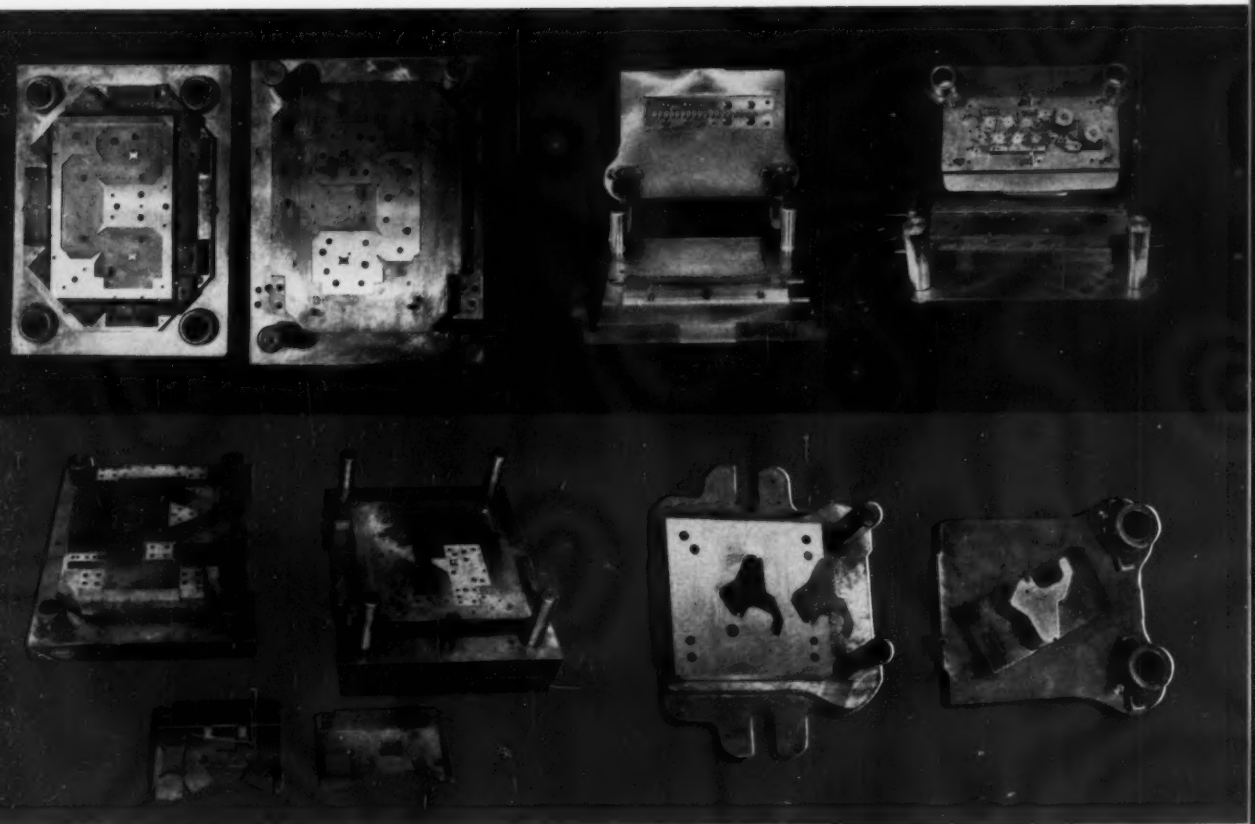
Write for catalog MP 607 today

AMERICAN GAS FURNACE CO. 1004 LAFAYETTE STREET, ELIZABETH, N. J.

Circle 1552 on Page 48-B

when you specify

DIE STEELS FOR COLD WORK



PICK THESE FOR PRODUCTION

COLONIAL NO. 6

First in the tool room for general-purpose versatility! Easy to machine; minimum size change in hardening; won't crack even in intricate shapes. Oil hardening, heat treats from low temperature.*

AIR HARD

The stay-put steel for dies, punch plates, fixtures that can't be ground to fit – no warping, no shrinking, no trouble. Deep air hardening; high strength; good wear resistance.*

OHIO DIE

High carbon, high chromium, air or oil hardening. Exceptionally tough at high hardness, this popular steel provides outstanding wear resistance with corresponding long die life in service.*

CROCAR

Top wear resistance with very high carbon content—and probably the least movement in hardening of any die steel. Balanced composition for easy machining. Air or oil hardening.

These grades are also available Precision Ground in flats or squares—ready for immediate production use. Satin smooth finish. Square, sharp corners. Protective wrapping. The sizes you want (in the hundreds!)

FIRST QUALITY · TOOL & SPECIAL STEELS · V/A

Circle 1553 on Page 48-B

VANADIUM-ALLOYS STEEL COMPANY

GENERAL OFFICES: LATROBE, PA.

DIVISIONS: Anchor Drawn Steel Co. • Colonial Steel Co. • Metal Forming Corporation • Pittsburgh Tool Steel Wire Co. • Vanadium-Alloys Steel Co.

SUBSIDIARIES: Vanadium-Alloys Steel Canada Limited • Vanadium-Alloys Steel Societa Italiana Per Azioni • EUROPEAN ASSOCIATES: Societe Commentryenne Des Aciers Fins Vanadium-Alloys (France) • Nazionale Cogne Societa Italiana (Italy)

and a sample of "Glas-Shot"—microscopic glass beads for use with all types of wet or dry blast equipment.

1399. Conversion Coatings

Pamphlet 1424C contains information on "Alodine", a chemical for producing a pre-paint conversion coating on aluminum. Handy selection chart also included. *Amchem Products, Inc.*

1400. Electrocleaner

The *Diversey Corp.* has published literature reviewing the advantages of "Diversey No. 1107" an electrocleaning compound designed to eliminate smut and provide effective cleaning action on "problems soils".

1401. Acid Electropolish

Technical Data Sheet No. 81 describes a liquid acid electropolish, "Electro-Gleam 55", that works equally well on carbon steel, aluminum, and stainless steel. *MacDermid Inc.*

1402. Barrel Finishing

Folder illustrates line of replacement barrels and complete barrel finishing units made by *Baird Machine Co.*

1403. Vapor Degreasers

4-p. Bulletin 21 describes vapor spray degreasers. Principle of operation, solvent cycle and a table of specifications on all models is included. *Phillips Mfg. Co.*

1404. Phosphatizing Cleaner

Bulletin M-206 released by *Magnus Chemical Co.* covers "Bondtite 82-X3" a nonfoaming phosphatizing cleaner which provides optimum coating for paint adhesion.

1405. Automatic Polishing Machine

Packer Machine Co. has issued catalog sheets giving complete engineering and production specifications on five types of automatic polishing and buffing machines.

1406. Zinc Coating

4-p. brochure describes "ZRC" (zinc rich coating) which is brushed or sprayed on iron or steel surfaces to provide galvanic protection. *Sealube Co.*

1407. Conversion Process

"Instruction Manual for Chem-Rite C-55" contains information about a single dip chromate conversion coating process for cadmium. *Hanson-Van Winkle-Munning Co.*

1408. Paint Spraying

Folder F9443 tells how to maintain the efficiency of water-wash paint spray booths. *Oakite Products, Inc.*

Welding and Joining Equipment

1409. "Guide to Better Welds"

80-p. booklet discusses causes and cures of common welding troubles, essentials for proper welding, and electrode selection. *Hobart Brothers Co.*

1410. Welding Stainless

Information concerning techniques for welding stainless steel is contained in *Lincoln Electric Co.* Bulletin 7300.2 entitled "Arc Welding Stainless Steel".

1411. Brazing Alloys

Data sheet from *Handy & Harmon* explains two alloys, "TEC and TEC-Z", which provide joint strengths between an average soft solder and a silver brazing alloy.

1412. Vinyl-To-Metal Adhesive

National Starch and Chemical Corp. will send data sheets and product information on a line of "VY-Metal" adhesives for vinyl-to-metal laminations.

1413. Plasmatrons

Pamphlet GP-5901 describes "plasmatron P-series" systems, capable of maintaining a continuous source of controlled temperature to 15,000° K. (which can vaporize any existing element). *Plasmadyne Corp.*

1414. Electron Beam Welding

Send for information on electron beam welding machine which combines research and production capabilities in one machine. *Sciaky Bros.*

1415. Welding of Foil

Reduction Sales Co. has made available 12-p. reprint of an article by J. Campbell entitled "Welding of Foil".

1416. Brazing Alloy

2-p. Folder No. 2.1.4 describes "Nicrobraz" brazing alloy and lists its engineering and brazing properties . . . recommended uses also included. *Wall Colmonoy Corp.*

1417. "Arc Welding News"

24-p. periodical from *Hobart Brothers Co.* is devoted to presentations of interesting articles and photographs on arc welding applications.

Inspection and Control Equipment

1418. Nondestructive Testing

12-p. Bulletin 00-105 describes line of ultrasonic testing equipment, portable industrial X-ray and magnetic particle inspection equipment and supplies. *Sperry Products Co.*

1419. Micro-Metallograph

Pamphlet discusses *E. Lietz, Inc.* "Micro-Metallograph" which features a large screen image for conference viewing and a high quality "plano-flat" field objective for best detail and large field of view.

1420. Motorized Testers

Motorized "Kentrall" hardness testers reduce operator error, increase reproducibility of test results and raise productive capacity. Bulletin CRS 60 from *Torsion Balance Co.*

1421. pH Meter

Brochure 720-C contains information on the "Model N" pH meter, which can also make millivolt measurements from 0 to ±420 mv. *Beckman Instruments.*

1422. Vacuum Probe

Pick up and handle miniature parts (made of any material) rapidly with a "Bazooka" vacuum probe. Information from *Air-Vac Engineering Co.*

1423. Carbon Determinator

16-p. catalog from *Harry W. Dietert Co.* explains both carbon and sulphur determinators as well as accessory equipment.

1424. Metallographic Equipment

Unitron Instrument Co. has issued Catalog 2-L describing line of metallographic equipment including a universal camera microscope.

1425. Universal Testing Machines

Bulletin 47, which reviews universal testing machines in capacities from 30,000 to 5,000,000 lb., can be obtained from *Tinius Olsen Testing Machine Co.*

1426. Superficial Hardness

Catalog RT-58 presents full line of Rockwell hardness testers and includes data on a superficial tester. *Wilson Mechanical Instrument Div.*

1427. Ductility Testers

Steel City Testing Machines, Inc. will send detailed specifications on ductility testers for quality control of incoming material.

1428. X-Ray Film

Pamphlet from *DuPont* details advan-

Circle appropriate number on Reply Card, p. 48-B

Introducing

A COUPLE OF SMOOTH OPERATORS

For a better finish start with AMGRIT **SHOT AND GRIT**

GENUINE ELECTRIC FURNACE STEEL ABRASIVES

ALLOY METAL ABRASIVE COMPANY

ORIGINATORS OF CAST STEEL SHOT

121 South Division Street, Ann Arbor, Michigan

Phone: NOrmandy 3-8529

Circle 1554 on Page 48-B

FOR RELIABILITY UNDER SHOCK LOADS AND HIGH HEAT...SPECIFY MIDVAC STEELS

Where metal parts must stand the sudden shock of heavy loads, as on plane landing gears . . . or the high heat of jet engines Midvac Steels offer the answer. The Midvac Process of consumable electrode vacuum melting produces metals with increased tensile, higher impact properties, improved stress rupture strength at elevated temperatures, and longer fatigue life.

Midvac Steels are offered in many alloys (some are shown in table below) as billets or forgings for the production of forgings to meet the most critical design specifications of today's space age. Complete details on Midvac Steels, plus comparative analysis of leading super alloys are available in new Midvac Steel Booklet. Write for your copy to . . .

MIDVALE-HEPPENSTALL COMPANY

Subsidiary of Heppenstall Company, Pittsburgh, Pa. **NICETOWN, PHILADELPHIA, PA.**

Alloy	Melting Process	Yield Strength .2	Ultimate Tensile Strength	Percent Elongation	Percent Reduction of Area
A-286	Air Melt	99,000 psi	132,300 psi	9.0%	14.7%
	Midvac	117,000 psi	150,500 psi	21.3%	33.8%
D6A-C	Air Melt	234,800	281,000	4.9%	20.6%
	Midvac	256,700	294,250	9.6%	28.4%
Tricent	Air Melt	238,600	284,500	6.1%	19.7%
	Midvac	254,300	291,600	10.3%	25.6%
901 Regular	Midvac	116,000	160,000	18.0%	25.0%
901 Hi-Strength	Midvac	131,000	179,000	19.2%	20.2%

Properties shown are averages of 25 heats

MH *Midvac Steels*

Circle 1555 on Page 48-B

tages of their industrial X-ray film, for critical definition and vivid images.

1429. Control Transducer

"Mechanical-To-Electrical Transducer" is the title of a descriptive treatise on the "Regohm" transducer, which summarizes a new design approach in a component used to control quantities such as position, tension and speed. *Electric Regulator Corp.*

1430. Laboratory Accessories

16-p. catalog from *Fischer Scientific Co.* covers line of corrosion resistant clamps, supports and holders for industrial, educational, clinical and testing laboratories.

1431. Magnetohydrodynamics

Brochure from *MHD Research* describes facilities and areas of research, including chemical processing, energy conversion, electric propulsion and space weapons.

1432. Particle Counter and Sizer

14-p. brochure illustrates "Casella" automatic particle counter and sizer suitable for particles in the size range of 1 to 200 microns. *Cooke, Troughton & Simms.*

1433. Superficial Tester

Pamphlet RT-58 describes superficial hardness tester and illustrates line of Rockwell hardness testers. *Wilson Mechanical Instrument Div.*

1434. Electrolytic Polisher

Ercona Corp. has released literature illustrating electrolytic polisher which permits constant observation of the etching processs.

1435. Testing Machines

Riehle Testing Machines Div. offers literature on complete line of testing machines and accessory equipment.

1436. Information Searching

Brochure discusses documentation service which delivers the world's current metallurgical literature to you every two weeks in digest form. *American Society for Metals.*

1437. "Testing U.S.A."

4-p. bi-monthly bulletin contains news of machines and test methods for all types of testing problems. *Testing Machines Inc.*

1438. Plasma Spectrograph

Plasma research spectrograph for use in plasma diagnostics and high-temperature gas research is described in pamphlet from *Baird-Atomic, Inc.*

1439. Inspection Equipment

4-p. Leaflet No. 130 discusses single frequency, nondestructive inspection equipment for detecting flaws in nonferrous, nonmagnetic metals. *Magnetic Analysis Corp.*

1440. Direct-Reading Spectrometer

Baird-Atomic, Inc. has published Bulletin SC-1 on direct-reading spectrometer which gives chemical composition in minutes.

1441. Fluorescent Penetrant Test

Folder from *Magnaflux Corp.* details the advantages of inspection with "Zyglo", a fluorescent penetrant inspection technique for nonmagnetic materials.

1442. Hardness Testers

Bulletin CRS 60 explains motorized "Kentrall" hardness tester. Major test loads are removed automatically, reducing operator error and increasing productive capacity. *Torsion Balance Co.*

1443. Spectroscopy Equipment

Brochure from *Radio Corp. of America* illustrates and reviews complete line of instrumentation for X-ray diffraction and spectroscopy laboratories.

1444. Instrument Charts

Catalog G100-6 reviews line of instrument charts such as strip charts available in 3, 4 and 12 in. widths and circular charts in 8, 10 and 12 in. diameters. *Minneapolis Honeywell.*

1445. Universal Testing Machine

Get the full story on the "Mark B" universal testing machine with positive guiding of the loading crosshead. *Wiedemann-Baldwin Co.*

1446. Universal Tester

Catalog sheets explain universal tester which can perform tensile, transverse, and compression tests. Capacities from 100 to 40,000 lb. *Detroit Testing Machine Co.*

1447. Speed Press

Pamphlet from *Buehler Ltd.* describes a "No. 1330 AS Speed Press" for rapid preparation of mounted metallurgical samples.

1448. Portable Hardness Tester

The "King" portable hardness tester makes all Brinell hardness tests quickly . . . accurately . . . anywhere. Specifications from *King Tester Corp.*

1449. Spectrographic Electrodes

National Carbon Co. has released a pamphlet on "Grade SPK" preformed electrodes of highest purity and uniformity for emission spectroscopy applications.

1450. Industrial X-ray Film

Type "AA" and Type "M" X-ray film is now available on rolls in 200 ft. lengths in three widths—16, 35 anl 70 mm. Further details from *Eastman Kodak Co.*

1451. Materials Testing

Catalog on advanced materials testing techniques is available from *Instron Engineering Corp.*

1452. Laboratory Metallograph

The "Model 2400P" metallograph is designed for maximum efficiency. Camera focuses automatically while you examine specimen through the microscope. Literature from *American Optical Co.*

1453. Hardness Testing

Booklet from *Clark Instrument Inc.* summarizes data on hardness testing; also contains hardness conversion chart.

1454. Research Metallograph

Bausch & Lomb metallographs help industry boost output and maintain quality by providing detailed magnified images for routine work and advanced research. Catalog E-240.

Production and Casting

1455. Heat Treatment of Stainless

24-p. research report "Heat Treatment and Properties of Cast, Hardenable Stainless Steels" is offered by *WaiMet Alloys.*

1456. Gas Generators

Rolock Inc. offers 4-p. Catalog Section 24A on reversible endothermic gas generators in rated capacities of 500, 750, 1000 and 1500 cfh.

1457. High-Vacuum Components

8-p. catalog summarizes complete line of high-vacuum mechanical and diffusion pumps, valves, gages, accessories, portable pumping systems, coaters, furnaces, electron beam welders, altitude chambers and freeze-drying equipment. *NRC Equipment Corp.*

1458. Control Motors

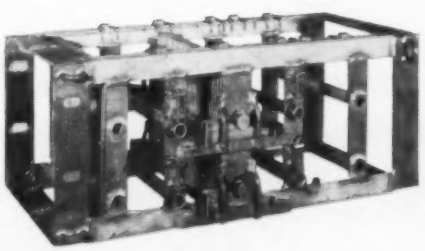
Minneapolis Honeywell has released information on "Actionator" heavy-duty electrical control motor. More torque, more precise positioning for industrial valve and damper applications.

1459. Ferroalloy Additions

Use of ferroalloys in pre-weighed bags reduces handling losses, improves in-

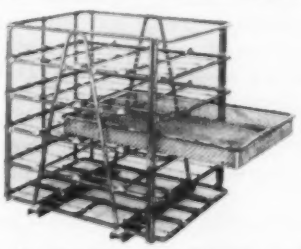
Circle appropriate number on Reply Card, p. 48-B

HOW ARE YOU FIXED FOR FIXTURES?



No. 369—Fast loading and unloading lock-tight fixture for holding large quantity of saw blades during heat treating, drenching.

Stanwood has successfully designed and manufactured a wide variety of fixtures to handle parts through heat treating. Describe the part you want to heat treat and we'll recommend a practical, time-saving fixture—constructed of alloys that resist thermal stresses, of course. Send for Catalog 61 describing baskets, trays, fixtures, carburizing boxes, pots, retorts and furnace parts.



No. 379—Fixture or rack for holding five trays. Easy to load and handle—better utilization of furnace space.

No. 396—Fixture for handling shafts, a large number of which can be stacked vertically for heat treating without touching each other.

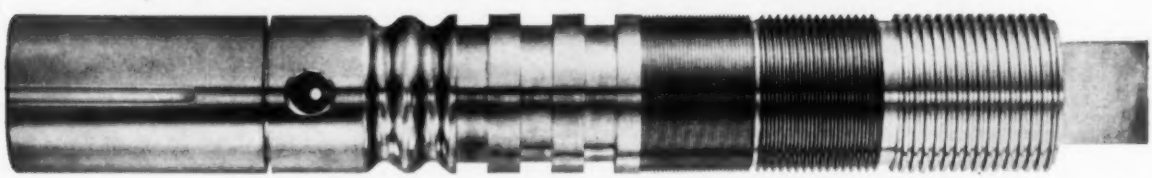
STANWOOD HEAT TREATING EQUIPMENT **CORPORATION**

4817 W. CORTLAND ST., CHICAGO 39, ILLINOIS

Circle 1556 on Page 48-B

THEY LAUGHED WHEN WE SAT DOWN TO PLATE...

they didn't know about KANIGEN®



This shaft was turned. It was key-slotted, drilled, tapped and shouldered. It was threaded, milled, grooved and chamfered. It was step-bored, with three inside diameters. Who could plate a piece like this all over—inside and out—and expect a uniform coating?

Well, anyone who used KANIGEN® could expect it—and get it. In fact, we made this piece especially to prove it.

The KANIGEN® process for chemical nickel alloy plating produces a uniform thickness of coating, regardless of the contours of a part. This uniformity permits full machining operations prior to coating, with no subsequent cleanup.

KANIGEN® offers corrosion resistance equal or superior to that provided by wrought or electrolytic nickel.

For complete technical details write or call your nearest General American office. Ask for Kanigen Bulletin No. 258. You'll find that with plating as in so many other industrial areas, *it pays to plan with General American.*

Kanigen Division

GENERAL AMERICAN TRANSPORTATION CORPORATION

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KANIGEN GENERAL AMERICAN TRADE MARK

Circle 1557 on Page 48-8

ventory control and provides for accurate alloy additions. Pamphlets F-20,121 and F-20,138. *Union Carbide Metals Co.*

1460. Induction Stirrers

Produce better steel faster with *Asea Electric Inc.* induction stirrers. These units accelerate reactions and develop homogeniety in the steel.

1465. Vacuum Slide Calculator

"Series H Microvac" pumps offer more pumping performance per dollar. Information and calculator from *F. J. Stokes.*

1474. Nickel Additions

Pamphlet from *Foote Mineral Co.* gives information on nickel additions in briquet and powder form, for faster alloying.

Parts, Forms, Shapes

1476. "The Mainspring"

The August-September issue of this periodical contains an article, "Another Method of Protecting Springs—Mechanical Plating". *Associated Spring Corp.*

1477. Flexible Hose

12-p. Bulletin 605 includes selection and installation information on "Flexaust" industrial hose and ducts for moving air, dust, fumes and materials via pressure, suction or gravity. *The Flexaust Co.*

1478. Contour-Rolled Stock

D. E. Makepeace Div., Englehard Industries will send literature discussing contour-rolled stock produced to tolerances as close as 0.001 in. with temper fully controlled.

1479. Die Springs

Information on the selection and use of die springs and accessories is contained in 8-p. catalog from *Producto Machine Co.*

1480. Industrial Floors

Bulletin 3-3 gives details on "Atlas" industrial floors of acid brick which resist corrosion and wear and minimize maintenance. *Atlas Mineral Products Co.*

1481. Wire Cloth

129-p. catalog from *Cambridge Wire Cloth Co.* contains data on brazed, seamless, teflon-coated, and other types of wire cloths and screens.

1482. Embossed Sheet

Bulletin 760 from *Roll Formed Products Co.* describes an embossing technique which permits application of virtually any embossed design to stainless steel, aluminum or anodized shapes.

1483. Self-Locking Blind Nut

Standard Pressed Steel Co. has published folder which reviews the principle of operation of "Davis" self-locking blind nuts and suggests possible applications.

1484. Roll Catalog

Barclay Machine, Inc. has issued Bulletin 601 which discusses rolls for any application. Fabricated or cast, bare or covered, available in a wide range of sizes and types.

1485. Steel Tubing

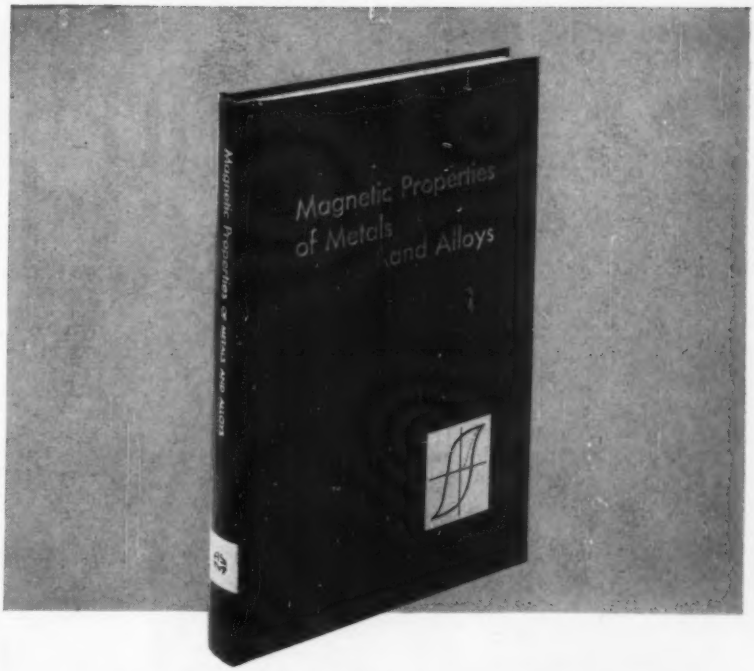
Ohio Seamless Tube Div. will send specifications on welded steel tubing in sizes up to 7½ in. OD, and square tubing up to 6 by 6 by 0.259 in. wall.

1486. Self-Locking Locknuts

4-p. folder released by *Klincher Locknut Inc.* presents stress analysis (photoelastic) of double-locking locknuts, which resist high frequency vibration and high temperatures.

1487. Toolsteel Tubing

Data Memorandum No. 14 offers a number of case histories on applications for toolsteel tubing—where strength and hardness, as well as wear, abrasion, and shock resistance are required. *Superior Tube Co.*



At last . . . a complete treatment of the newest advances in magnetics, "definitive, practical"!

Here, for the first time, is a book that goes far beyond academic studies of magnetic properties and brings you up-to-date with current developments. Seventeen outstanding engineers and scientists describe the most significant advances in magnetic phenomena that underlies future developments and technologies . . . in the electrical and electronic industries' already explosive expansion. Presented in thirteen clearly written, illustrated chapters, and eight appendices. This *best seller* belongs in *your* collection of important books. Examine its breadth of content and order today!

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- **Magnetic Properties of Thin Films**
- **Magnetic Properties of Fine Particles**
- **Time Effects in Magnetization**
- **Magnetostriction**
- **Magnetomechanical Damping**
- **Spin Clusters in Iron Near the Curie Temperature**
- **Magnetic Annealing**
- **Film Preparation**
- **Measurements with Magnetic Fields**
- **Anisotropy Caused by Texture**
- **Measurements with Light Microscopy**
- **Anisotropy from Magnetoelastically Induced Strain**
- **Relationship Between the Exchange Parameter and the Exchange Integral**
- **Resonant Frequencies in Metallic Films**
- **Line Width and Resonant Frequency**

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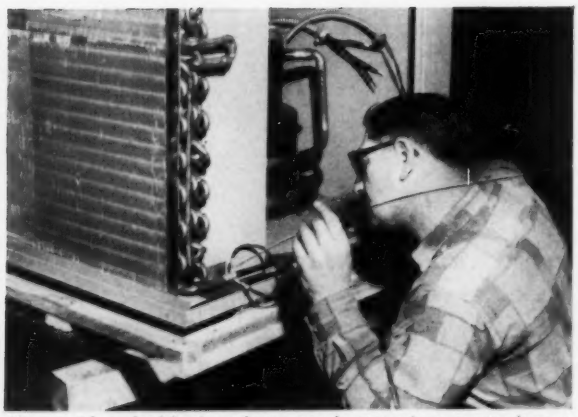
HOW TO MAKE 4,999 JOINTS WITHOUT FAIL



Here, with a double tipped oxyacetylene torch, operator brazes condenser coil joints. This condenser-compressor assembly contains 30 hook-up joints, not counting return bends.

The unit evaporator, located inside the house, contains 36 hand-brazed SIL-FOS 5 joints.

International Heater Does it With HANDY & HARMAN SIL-FOS 5

Production statistics of this manufacturer of heating and air-conditioning equipment show that perhaps one in five thousand hand-brazed joints may need touching up. This is a micrometer measurement away from absolute perfection.

One of the Utica, New York, company's products is a home air conditioner that utilizes the existing duct work of the structure's hot-air furnace. Its novelty lies in the fact that the unit's compressor and condenser are located outside the house for noise-free coolness inside the home.

The unit's evaporator is installed on top of the furnace for simple tie-in to the plant's ducting for hot-weather operation.

Shown here in production is International's Model 5-5B of 5 ton capacity.

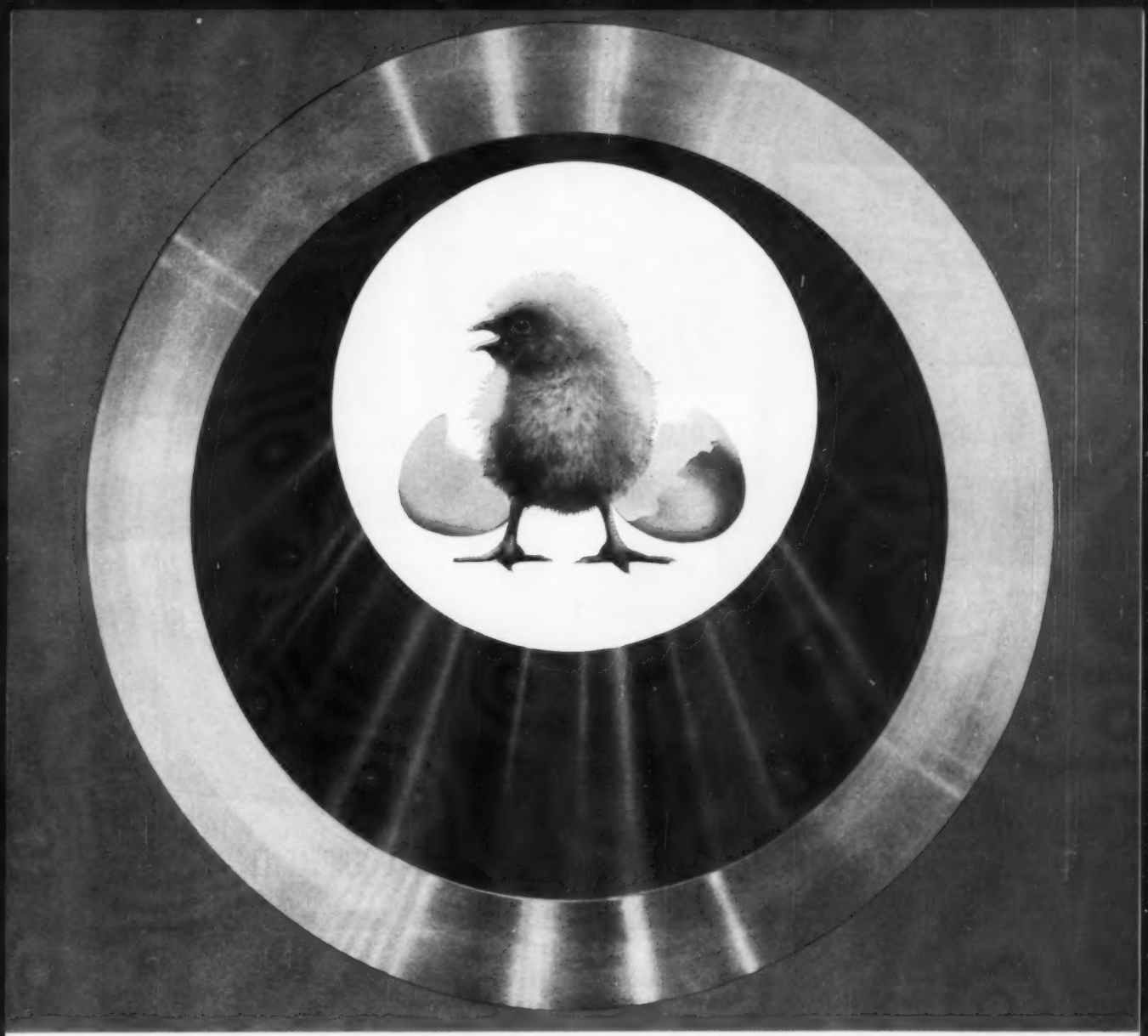
This "joint in quantity" record is being duplicated by SIL-FOS 5 silver alloy brazing in the manufacture of heating, air-conditioning and refrigeration equipment everywhere. Its strength, air- and leak-tightness and ease of application are some of the reasons that make Handy & Harman SIL-FOS 5 brazing one of the *surest* metal joiners in existence. We'd like you to know more about SIL-FOS 5 and the job it can do for you in joining copper and copper alloys in any shape, size and complexity. Our Bulletin 20 deals with this in a complete and informative manner. A request to Handy & Harman, 850 Third Avenue, New York 22, N.Y. will bring you your copy.

Your No. 1 Source of Supply and Authority on Brazing Alloys

HANDY & HARMAN

General Offices: 850 Third Avenue, New York 22, N.Y.

Circle 1559 on Page 48-B



WHAT'S NEW IN TUBING?

Here's another ACIPCO "first"... ACIPCO CERAM-SPUN®, the ceramic mold process* that offers greater versatility in design, new concepts in economy.

WHAT THESE ADVANTAGES MEAN TO YOU! ACIPCO is not limited by equipment sizes. Now, for the first time, you can order the exact tube O.D. you need... from 2.25" to 50". As-cast lengths can vary from 4 feet to 20 feet, longer lengths are made by welding; and wall thicknesses range from .25" to 8". Furthermore, these tubes can be furnished with the exact combination of physical, chemical, and metallurgical properties required by your specifications.

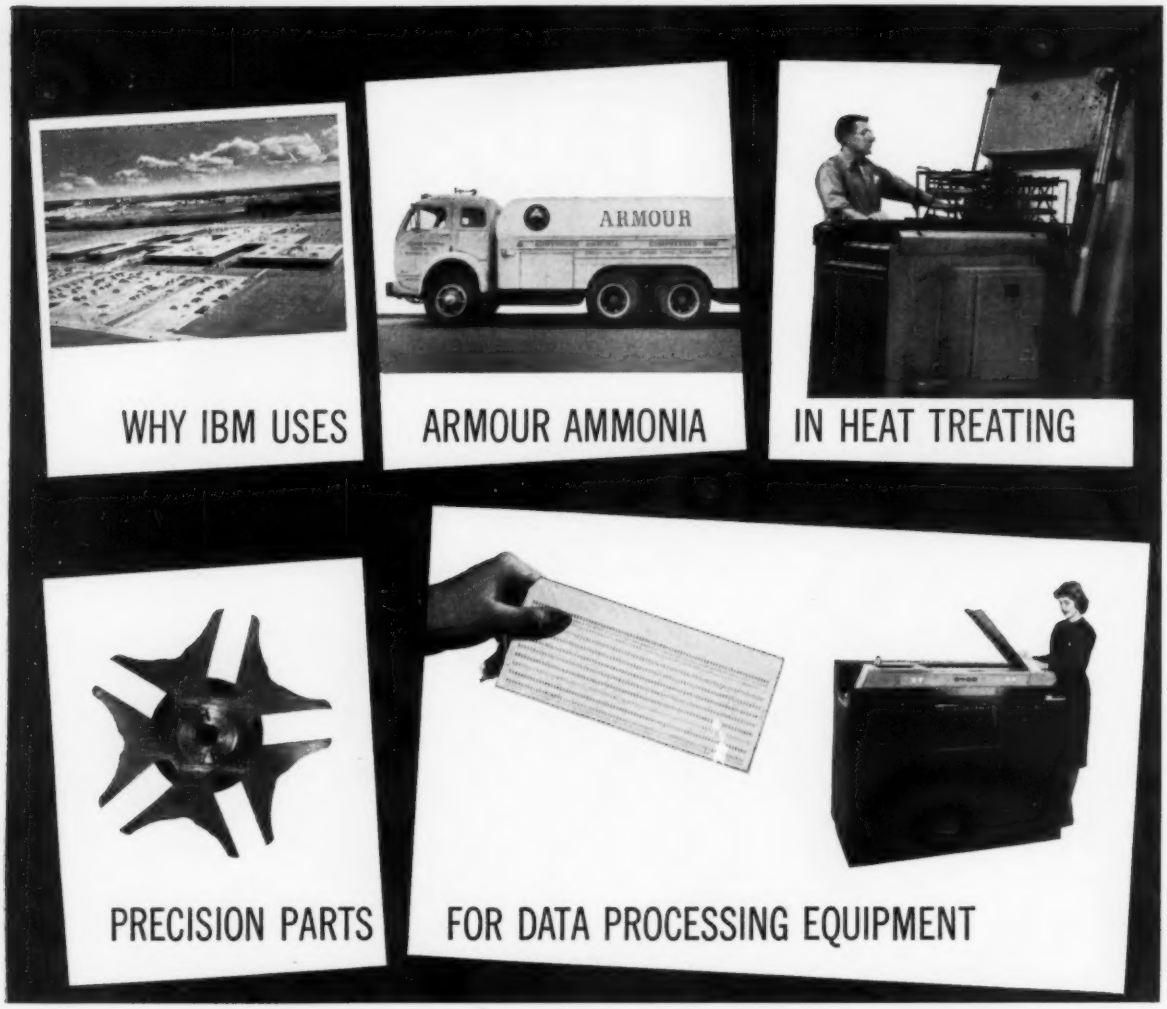
THE RESULT: YOU SAVE MORE! No more unnecessary metal waste or excessive machine charges.

Too, ACIPCO's complete "under one roof" operations — including heat treating, machining and welding — eliminate the delays and additional high costs often involved in buying from multiple sources. Before you order another steel tube . . . first investigate the many advantages ACIPCO offers. Contact ACIPCO STEEL PRODUCTS, Division of American Cast Iron Pipe Company, Birmingham 2, Alabama.

*Patent applied for

ACIPCO CERAM-SPUN®
STEEL TUBING

Circle 1560 on Page 48-B



Precise heat treating results are a must for vital components of the electronic marvels produced by International Business Machines Corp. in Rochester, Minnesota.

IBM heat treats about four million parts a year in Armour ammonia atmospheres. Heat treating processes used include carbonitriding, nitriding, annealing and brazing. A good example of one of these parts is the Geneva Star Wheel shown above, which must be precise and as wear-resistant as possible.

Helping to create consistently fine results is the uniform, high quality of Armour ammonia. Tested after filling to be at least 99.98% pure when delivered, every tank truck of Armour ammonia meets IBM's rigid standards for heat treating.

Armour ammonia has been used since the plant opened 2½ years ago. But this confidence goes back further. Armour worked closely with IBM engineers in planning the initial installation, preparing blueprints, and choosing the proper ammonia equipment and parts. Armour technical men also inspected the system and helped to get it under way and running smoothly.

Prompt delivery from Armour's South St. Paul plant is also important to IBM. Operating around the clock, IBM often requires same-day or next-day service—and they get it from Armour.

Call Armour for ammonia. High purity assured (*every* cylinder and tank truck tested to be *at least* 99.98% pure)...fast delivery (171 distribution points across the country)...expert technical service (whenever needed and at no cost).

AMMONIA SALES

Armour Industrial Chemical Company

One of The Armour Chemical Industries

110 North Wacker Drive • Chicago 6, Illinois

Circle 1561 on Page 48-B

The ASM is the communications center for technical information wherever metals are produced, processed, fabricated, designed, tested and applied. Metal Progress, monthly engineering magazine of the Society, reports on engineering developments in these 11 major technological areas:

FERROUS METALS

NONFERROUS METALS

HEAT- AND CORROSION-RESISTANT AND ELECTRICAL MATERIALS

RADIATION AND NUCLEAR MATERIALS & EQUIPMENT

TOOL MATERIALS, CUTTING AND FORMING EQUIPMENT

INDUSTRIAL HEATING EQUIPMENT AND SUPPLIES

CLEANING AND FINISHING EQUIPMENT AND SUPPLIES

WELDING AND JOINING EQUIPMENT AND SUPPLIES

INSPECTION AND CONTROL EQUIPMENT AND SUPPLIES

PRODUCTION AND CASTING EQUIPMENT AND SUPPLIES

PARTS, FORMS AND SHAPES FOR DESIGN AND APPLICATIONS

April, 1961 issue
METAL PROGRESS

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Metal Progress April, 1961 issue

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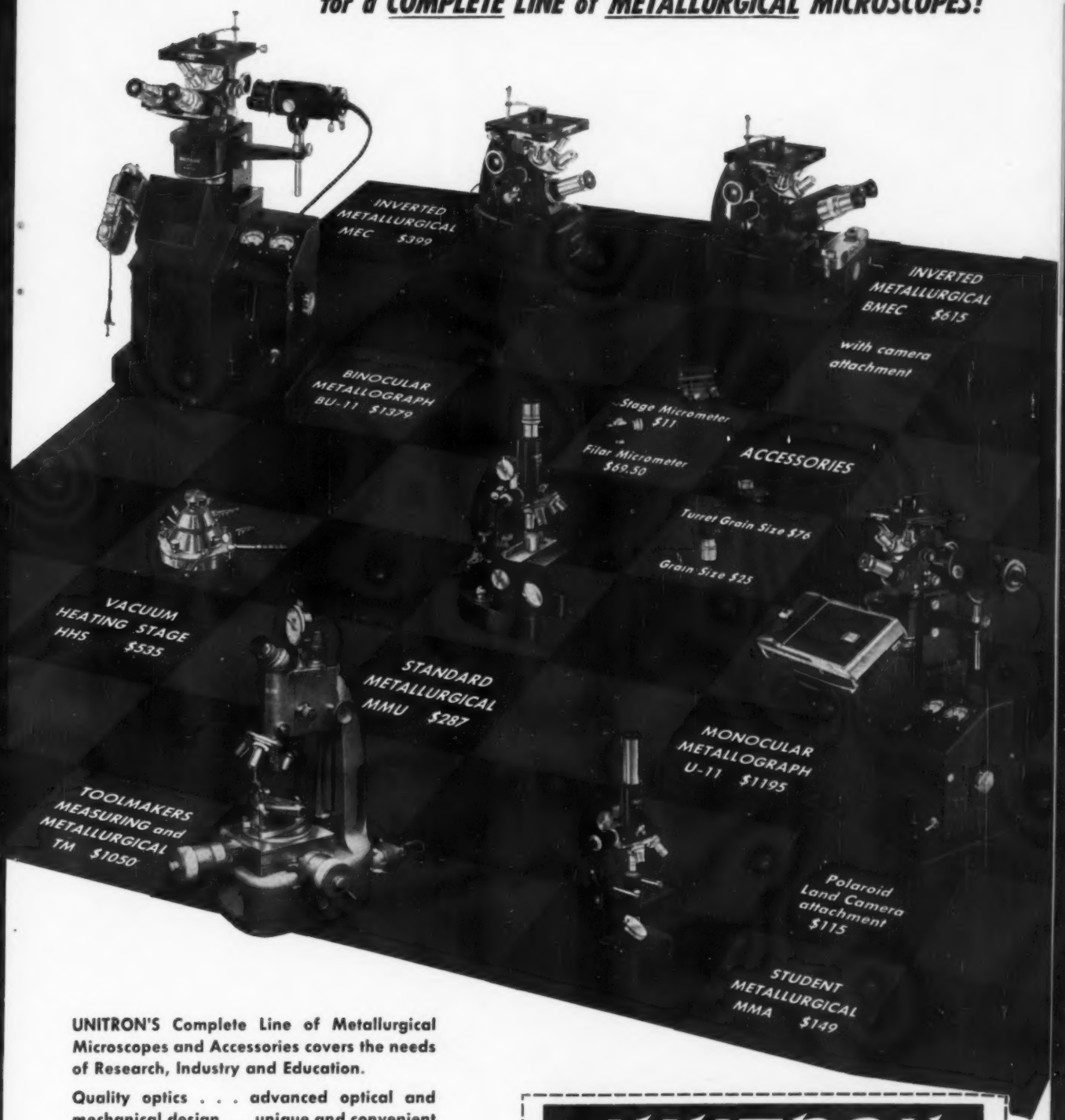

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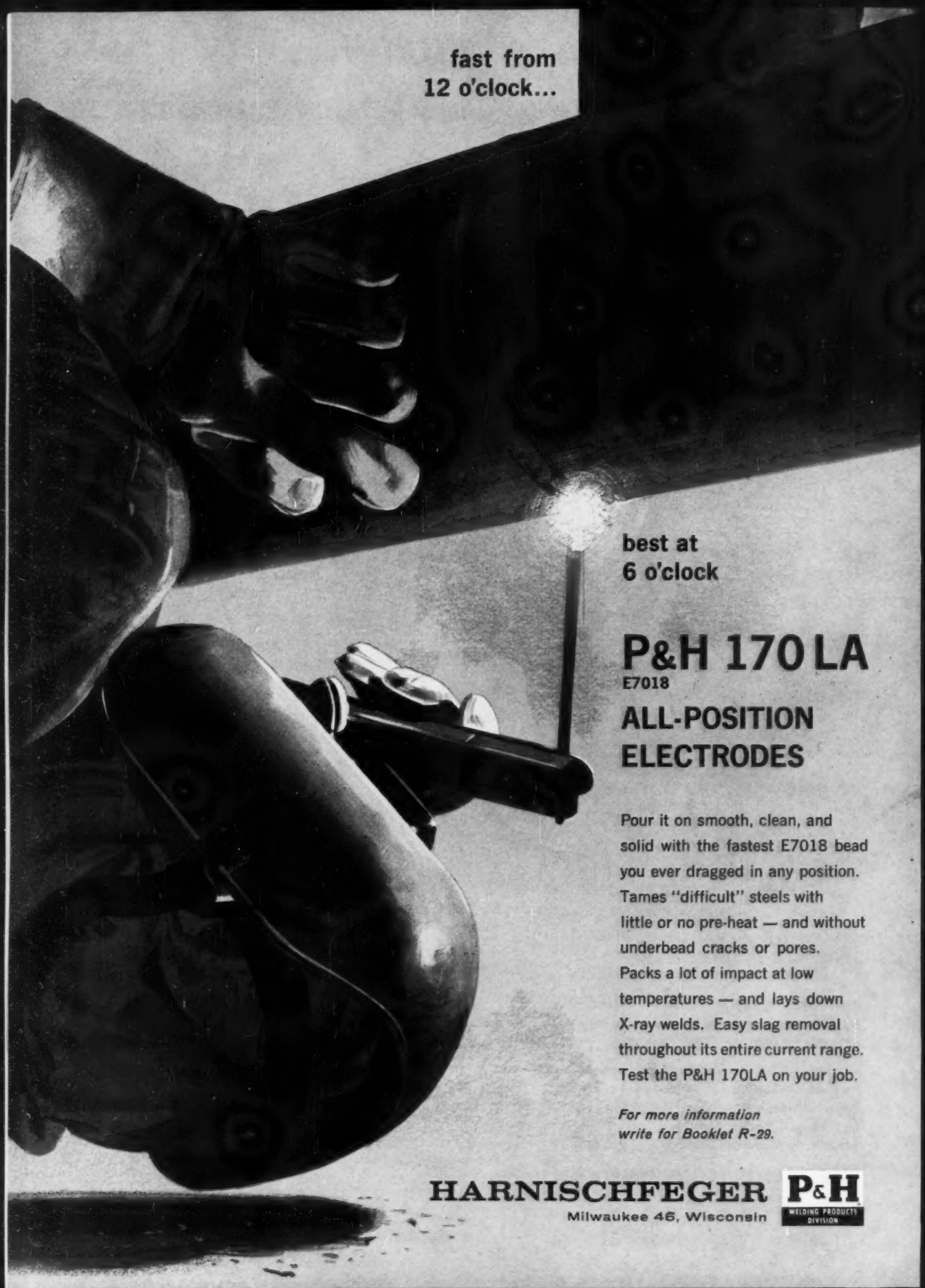

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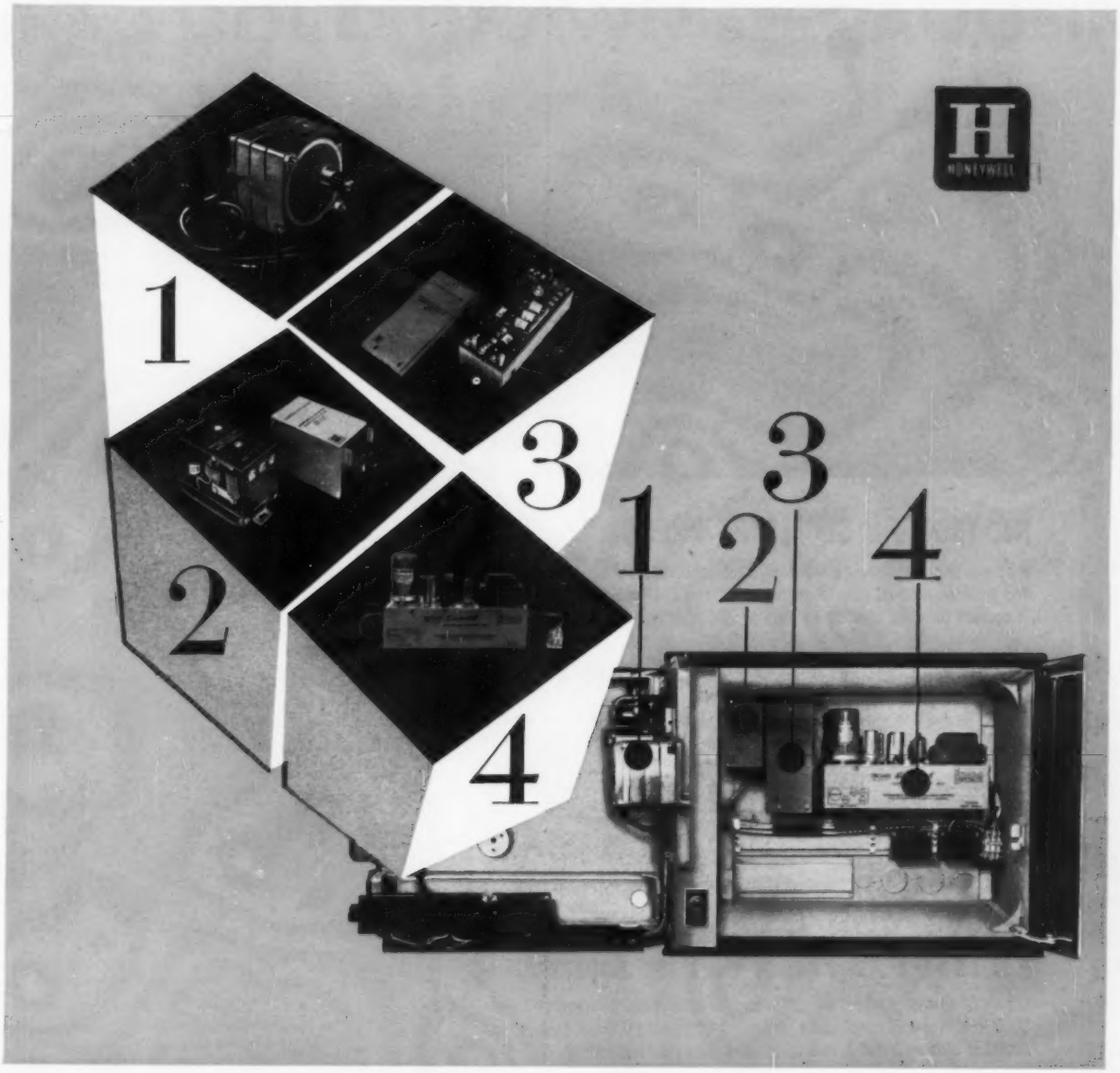

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First in Control

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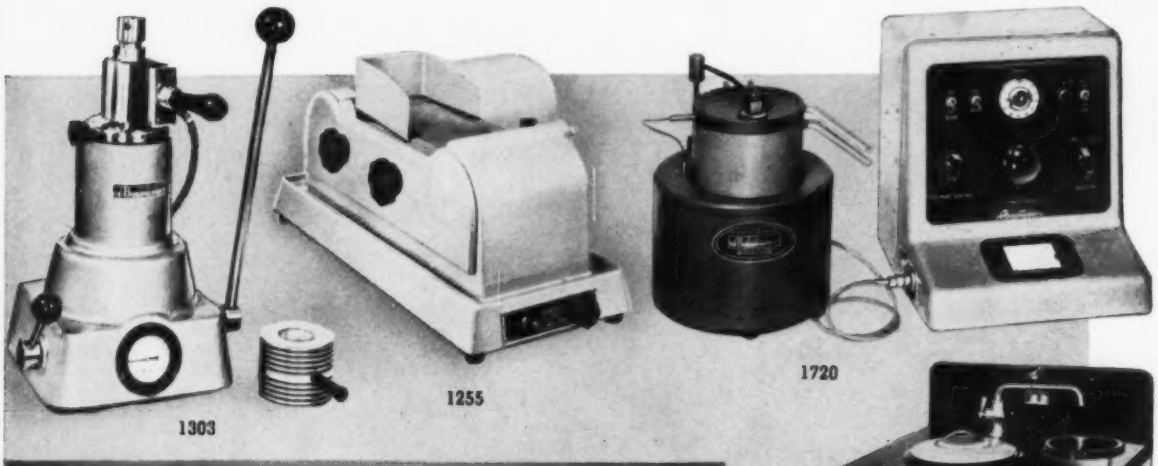

No. 1303 AB SIMPLIMET PRESS

for mounting metallurgical samples is of especially strong construction and provides unusual ease in operation. 1" and 1¼" molds are available. It accepts bakelite powder, bakelite premolds or transoptic powder.

No. 1255 AB SURFMET BELT SURFACER

offers the advantages of wet grinding on silicon carbide belts. Features include fast, accurate grinding, external coolant and centering controls, easy belt change, and access for large samples with good splash protection.

No. 1720 AB ELECTROLYTIC POLISHER

is designed for trouble free service, ease of operation and versatility in the electropolishing of metallurgical samples.

No. 1851-1 AB Polimet Polishing Apparatus

has an 8" diameter wheel with infinitely variable speed between 100 and 1200 RPM which is electrically controlled by turning a small knob. It is available also in 2 and 3 unit tables and for custom mounting.

No. 1470 AB HANDIMET GRINDER

provides the most rapid and convenient way of fine grinding metallurgical samples by hand. Four grades of adhesive backed abrasive papers are arranged side by side with coolant flowing over them for fast clean cutting.

No. 1000 AB CUT-OFF MACHINE

is a heavy duty unit for abrasive cutting of metallurgical laboratory samples. It has a 5 HP motor, 12" abrasive wheel, built-in cooling system using jets or underwater cutting and a machine tool type positioning slide.

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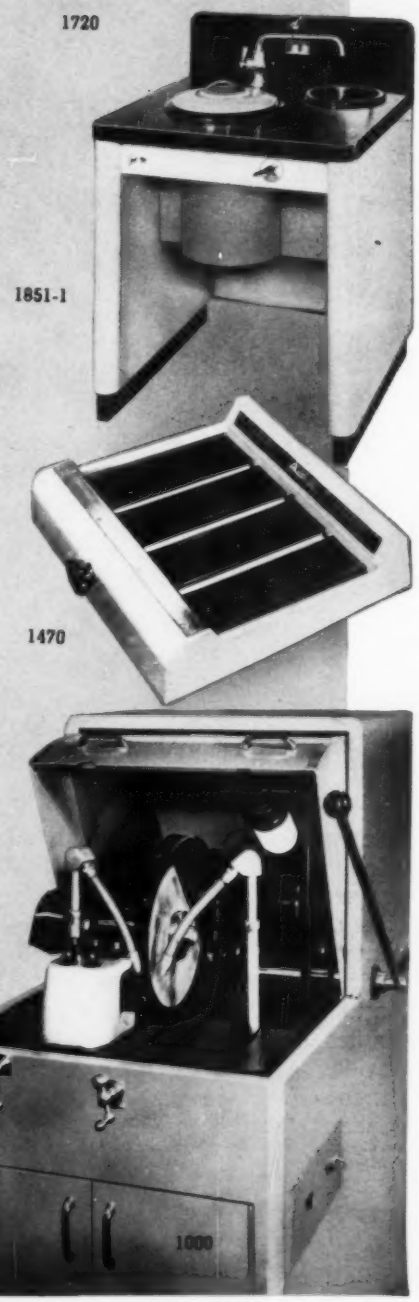

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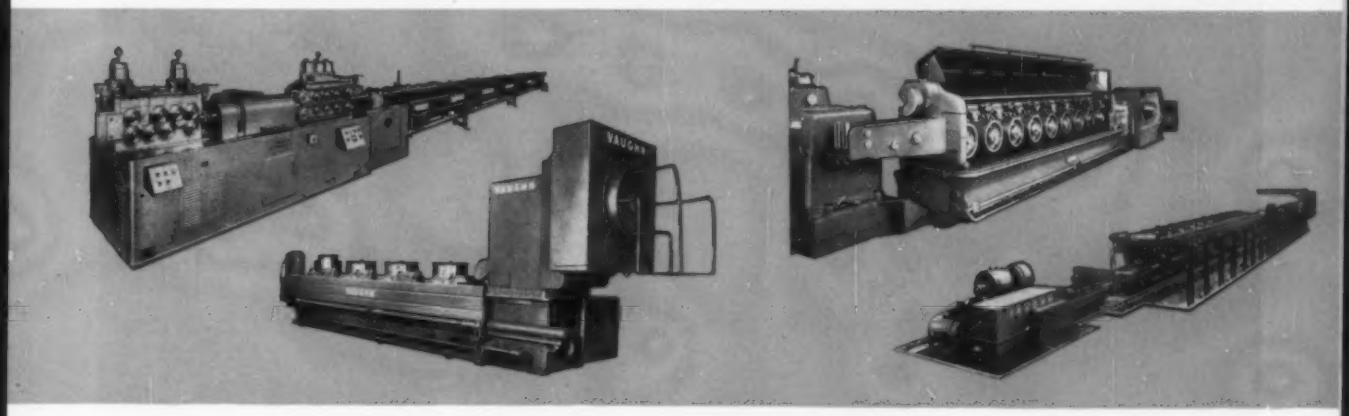
IF IT'S COLD DRAWN SEE VAUGHN!



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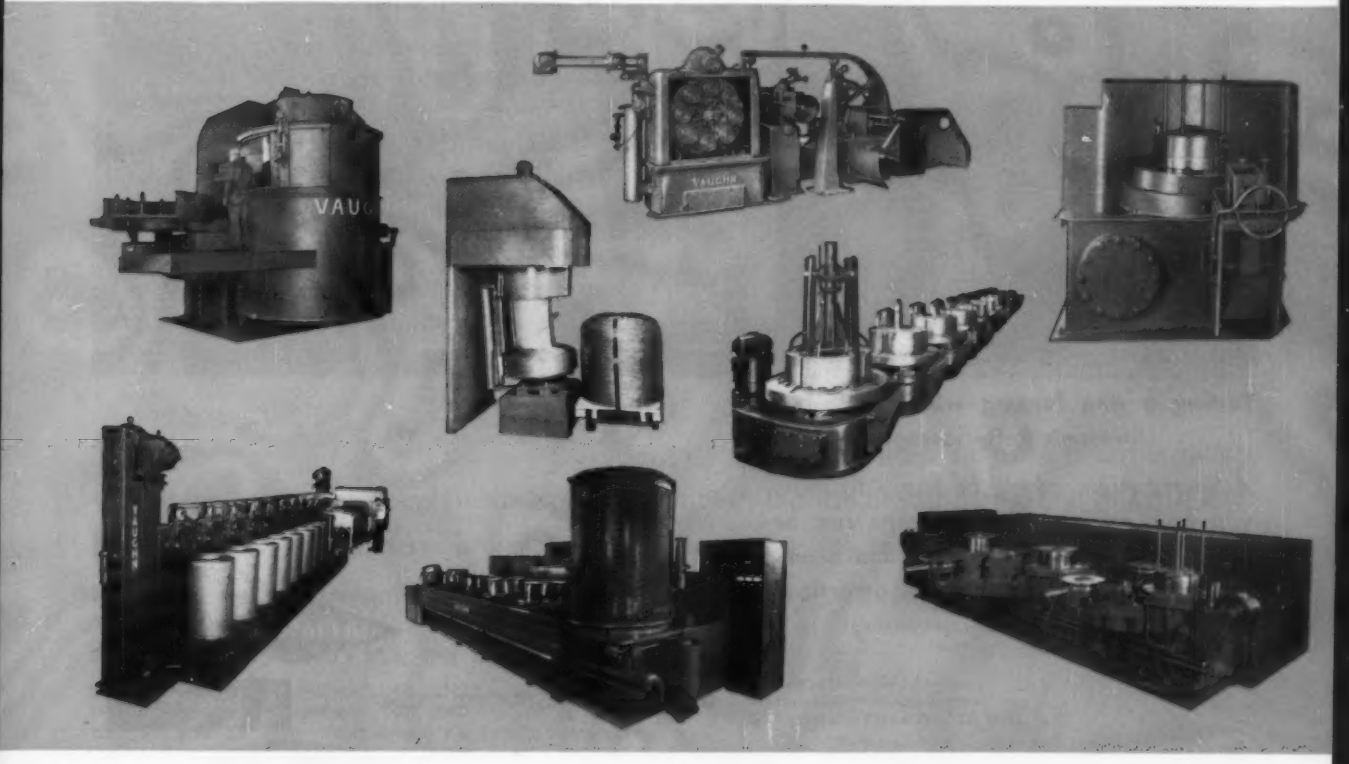

When cold drawing is part of your production picture, come to the leading equipment manufacturer for every service you may require . . . consultation, design, layout, quotations... and the broadest choice of cold drawing and related machinery in the world. You'll find Vaughn co-operation as complete as our resources. Let us serve you!

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"Quick on the Draw!"

THE VAUGHN MACHINERY COMPANY

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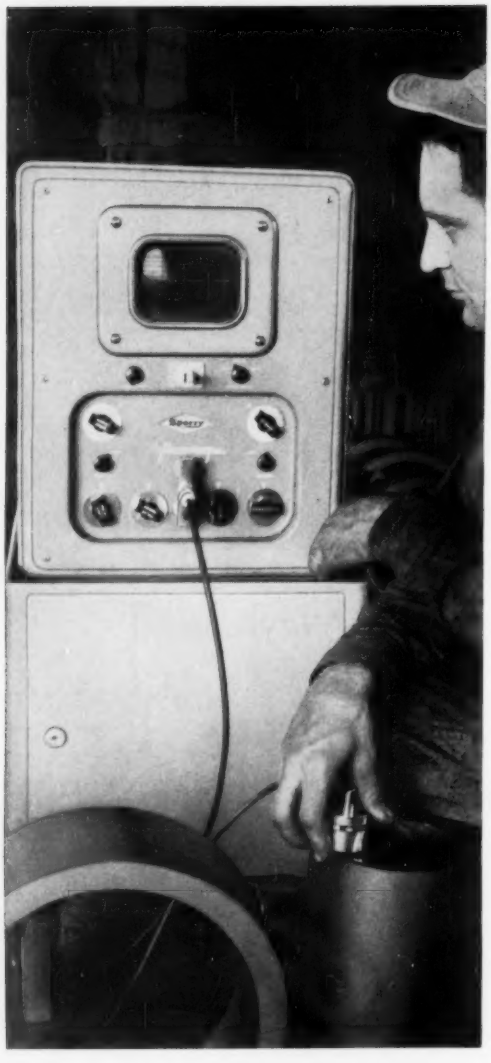

Testing a ring forging with the Sperry Ultrasonic Reflectoscope.

A Sperry engineer will be happy to show you how easily a Reflectoscope can be fitted into your production picture and how quickly its low cost can be amortized even by relatively small companies.

"ULTRASONIC TESTING DIRECTLY RESPONSIBLE FOR INCREASING OUR VOLUME 20%"

—Joseph Mancini, President
Monroe Forgings, Inc.
Rochester, New York

"Nondestructive testing with Sperry Ultrasonic test equipment has widened our sales potential greatly. We credit it with being directly responsible for increasing our volume a full 20%," President Mancini reports.

"Ultrasonic nondestructive testing has become an invaluable asset in many ways. Its capacity to find trouble before it starts has resulted in substantial savings in both production time and material costs. And it has enabled us to expand by effectively competing in fields demanding the utmost in quality and reliability."

Monroe Forgings is but one of hundreds of companies that are finding sure profit, as well as sure protection, in Sperry nondestructive testing.

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LEADER IN NONDESTRUCTIVE TESTING

X-RAY

MAGNETIC

SPERRY PRODUCTS COMPANY
DIVISION OF HOWE SOUND COMPANY

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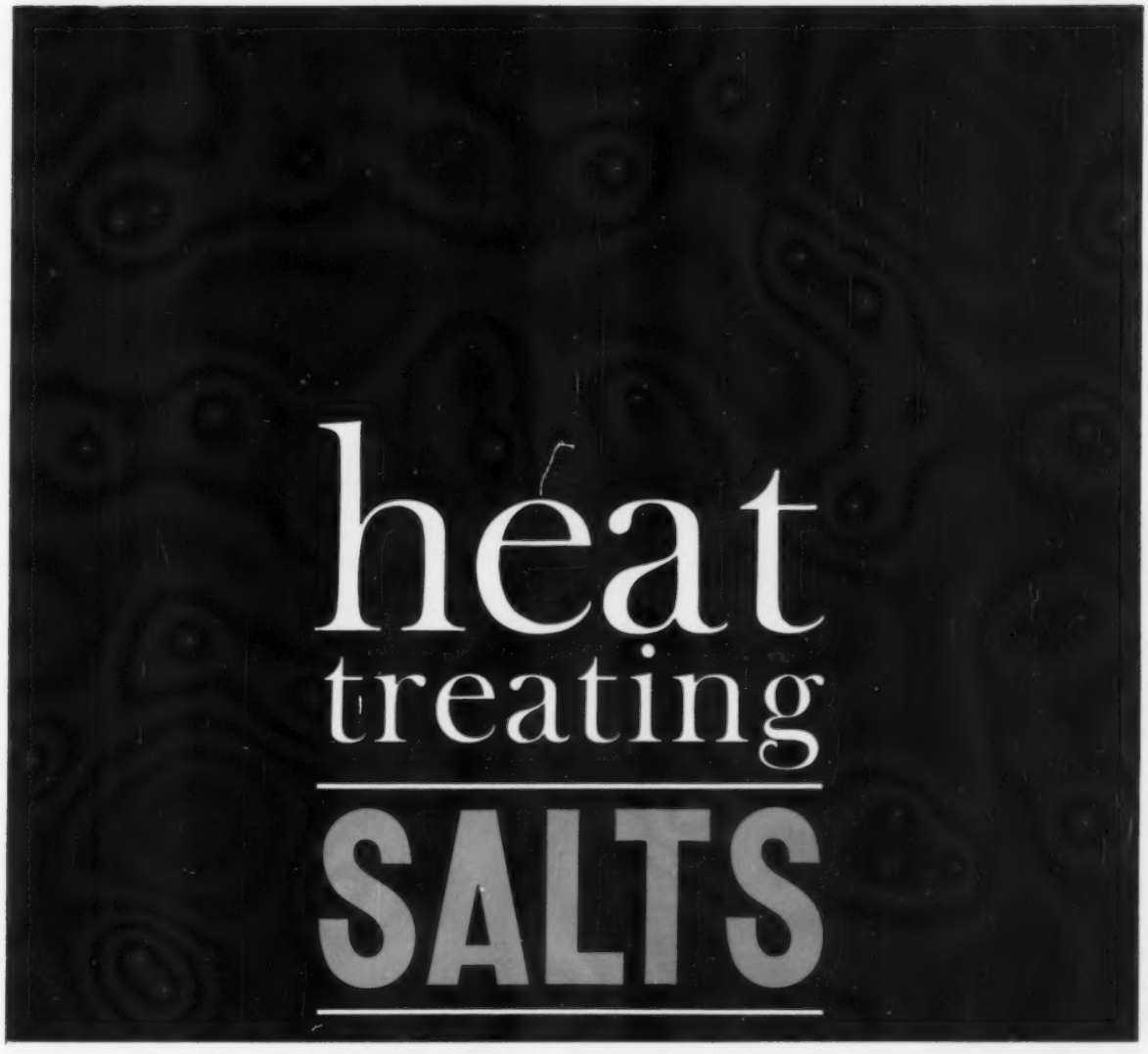

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Eliminate scaling and decarburization in heat treating, without special atmospheres – through the use of salt baths. Use AEROHEAT® heat treating salts for uniform, economical results in electric, gas or oil fired furnaces. For further information about Cyanamid chemicals for the metal industry or technical assistance, mail coupon.

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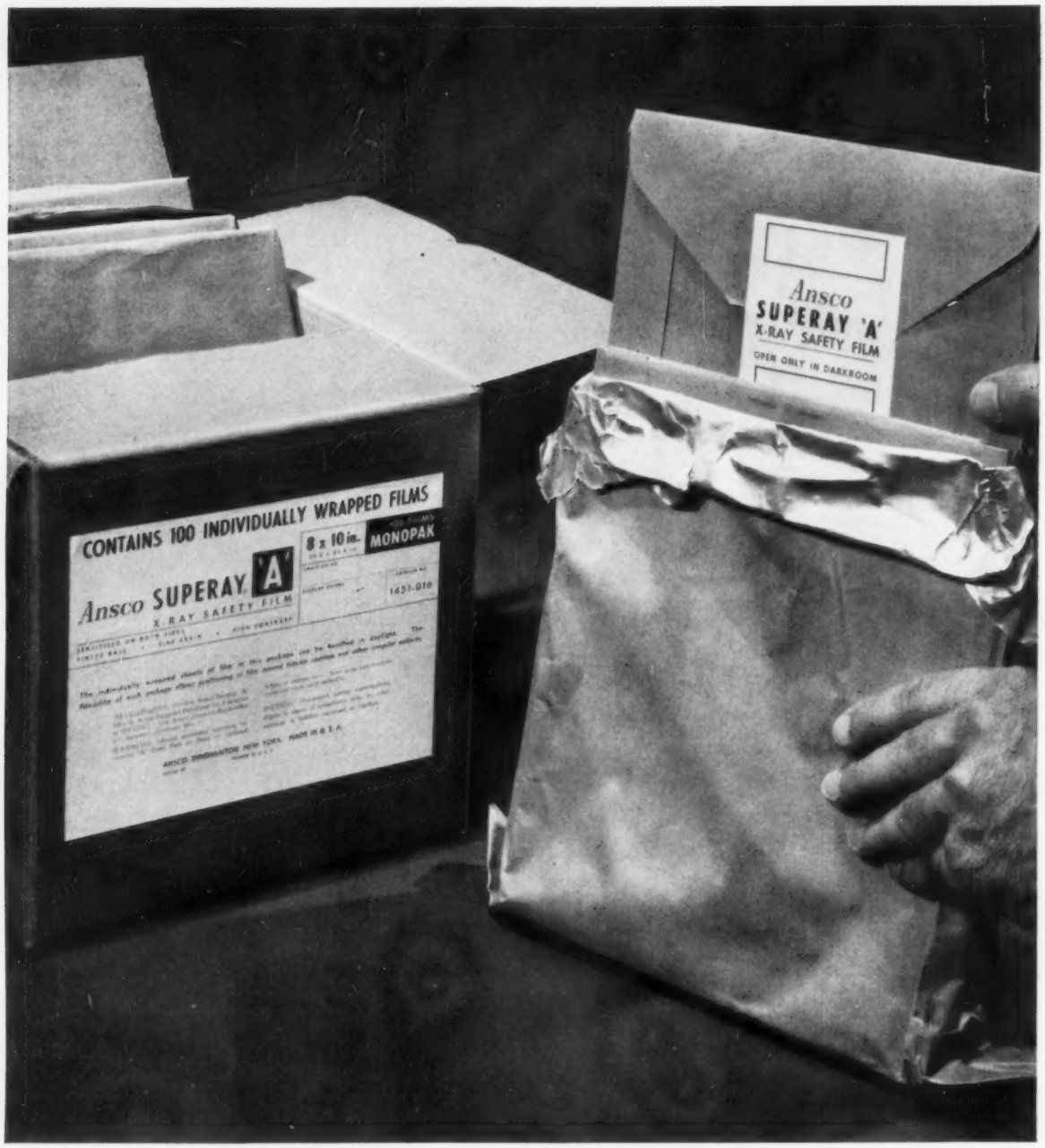

IMPROVE INSPECTION EFFICIENCY WITH ANSCO MONOPAK X-RAY FILMS

Modern non-destructive testing requirements call for fast and accurate flaw detection. That's why experienced technicians depend on Ansco Superay® 'A' and 'B' Monopak X-ray films . . . for quick and positive readings. Take advantage of the dependability and ease-of-handling convenience offered by Monopak. For information about how Monopak can improve your inspection efficiency write: Ansco Industrial X-ray Department, Ansco Division, Vestal Parkway East, Binghamton, New York.

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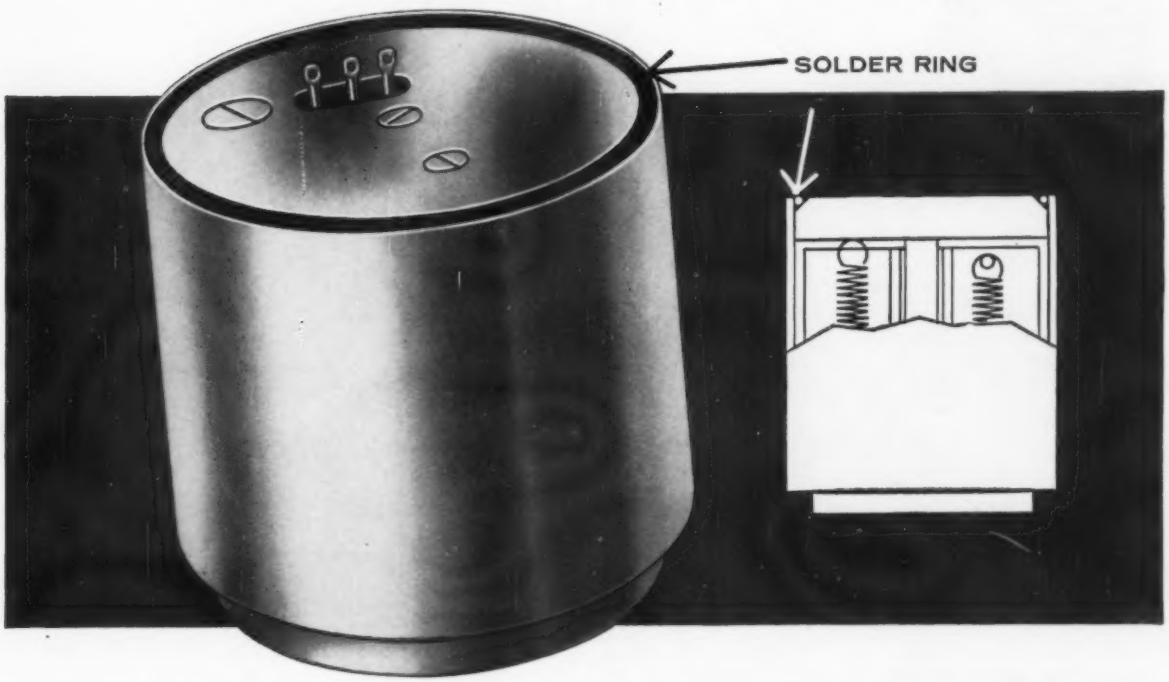
Circle 1497 on Page 48-B

Precision soldering 7 Times Faster...

with TOCCO* *Induction Heating*



When G. M. Giannini and Co., Inc., Pasadena, California, switched from old-fashioned methods to TOCCO Induction Heating they increased production of these high-precision accelerometers from 4 to 30 per hour—with a commensurate *decrease* in production costs.

Here's what a Giannini official has to say about the TOCCO installation: "Prior to using TOCCO for this purpose, we had tried soldering irons, normal torches, resistance sealing, and even threaded screw fittings, with uniformly poor results. Essentially, the TOCCO unit has permitted us to build, in production quantities, oil-filled hermetically sealed units that could not be produced in any other way."

Whether your production bottleneck involves soldering, brazing, heat treating or heating for forming it pays you to investigate TOCCO as an economical way to do it better, faster and at lower cost.

THE OHIO CRANKSHAFT COMPANY

Mail Coupon Today— NEW FREE Bulletin

The Ohio Crankshaft Co. • Dept. R-4, Cleveland 5, Ohio

Please send copy of "Typical Results of TOCCO Induction Brazing and Soldering".

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Circle 1498 on Page 48-8

only a **CLEAN-LINE®** furnace from hevi-duty brings you . . .

Only "Clean-Line" Heat Treat Furnaces from Hevi-Duty offer so many ways to speed production, cut maintenance and improve output. Consider these advantages:

1. Complete, automatic, "straight-through" operation from loading through quench.
2. Vestibule-housed transfer pusher head only under heat during 9-second transfer cycle. You get trouble-free operation.
3. Expansion seals for radiant tubes are at *cold* end. This system maintains tight atmosphere seal, lengthens tube life.
4. Externally located heat exchanger and pump for easy maintenance and high penetrating oil flow in the quench cycle.
5. Fan circulation for even distribution of heat *without* use of baffles.
6. Compact loading table — just 1½ baskets long — for savings in floor space.
7. Fuel-fired or electric models available.
8. Special options — automatic quench retractor, double-chamber design for two independent temperatures and two independent atmospheres, temperatures to 2100°F.

Suitable for carbonitriding, carburizing, bright hardening, annealing, normalizing and brazing, the standard "Clean-Line" furnace is used for heat treatment of metal to 1850°F. Complete systems are available . . . including heat treat and quench unit, gas generator, washer and tempering furnace.

Hevi-Duty's "Clean-Line" furnace is just one in a full range of products: heat treating furnaces, ferrous and nonferrous metal melting and holding furnaces, and industrial ovens — all available fuel-fired or electric. Get full details from your Hevi-Duty sales engineer or write to Hevi-Duty, Watertown, Wisconsin, for Bulletin D 100A.

HEVI-DUTY

Electric and Fuel-Fired Industrial Furnaces and Ovens

B P C

Hevi-Duty Electric Company, Watertown, Wis.

A Division of Basic Products Corporation

Circle 1499 on Page 48-8

who cares about the freezing process . . . *as long as it tastes good? Many production men, understandably enough, share the viewpoint of this small-fry. It doesn't matter how steel freezes in the ingot mold, just as long as the bar and strip and wire and other shapes perform well. Other than steelmakers, who should care about uniform material? You should care if you've ever run into trouble with stainless or high temperature alloys or tool steels. For higher reject rates, premature part failure, shortened tool and die life, increased production costs, and dissatisfied customers . . . all can be traced directly to the ingot. An ingot of weak structure or poor composition can mean trouble in every piece of steel that comes from it.*

That's why we say the exclusive MEL-TROL® process goes a step beyond quality control. It includes a new patented mold which controls the freezing process . . . forces impurities to the top of the ingot where they can be cut off and discarded. This MEL-TROL ingot is more uniform . . . freer from segregation. You get clean, sound, tough metal from surface to core in every lot of steel you order. Specify Carpenter MEL-TROL steels and avoid trouble in the future. Then you, too, can enjoy the luxury of saying: "I don't care how they make it as long as it performs so well!"

Carpenter steel

you can do it ***consistently*** better with Carpenter specialty steels for specialists

The Carpenter Steel Company, Main Office and Mills, Reading, Pa.
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Circle 1500 on Page 48-E

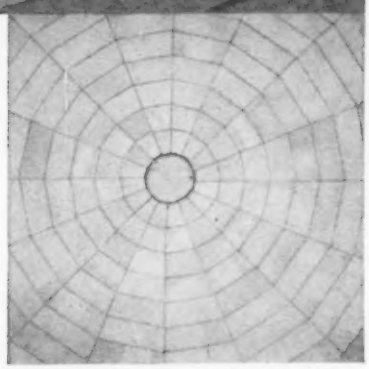
Bell-type annealing furnaces hold critical temperatures better—using J-M Superex

LEE WILSON ENGINEERING COMPANY, INC., STANDARDIZES ON J-M SUPEREX BLOCK INSULATION FOR PRECISION AND PERFORMANCE

In heat-treating furnaces, at temperatures to 1900F, Johns-Manville Superex® Block insulation provides greater efficiency and long operating life . . . because of its unique combination of low conductivity and low shrinkage at elevated temperatures. Control of critical processing temperatures is reached *and held* more easily.

Especially formulated from diatomaceous silica and asbestos, the large, strong, lightweight blocks of J-M Superex are cut with such careful precision that a furnace dome will support the weight of several workers during construction...*without any cement being used!*

This ideal combination of performance advantages and production skill is the reason Lee Wilson Engineering Co., Inc., employs J-M Superex for wall and dome insulation. It will pay you to insist on J-M Superex in your high-heat equipment. Write for details to Johns-Manville, Box 14, N. Y. 16, N. Y. In Canada: Port Credit, Ont. Cable: JOHNMANVIL



Inside Looking Up...*view from below the dome of a Lee Wilson bell-type furnace. Note close fitting between Superex blocks. This dome actually supports installation workers' weight* . . . without use of cement!

ONLY J-M SUPEREX BLOCK INSULATION GIVES YOU ALL THESE ADVANTAGES:

High Compressive Strength—only ⅛" compression under 85 lbs psi

Low Conductivity—.82 at 1000F mean temperature

Low Heat Shrinkage—2.7% linear shrinkage at 1900F

Large Size Blocks—12" x 36" blocks speed application, reduce number of joints. Yet blocks are light in weight for ease of installation

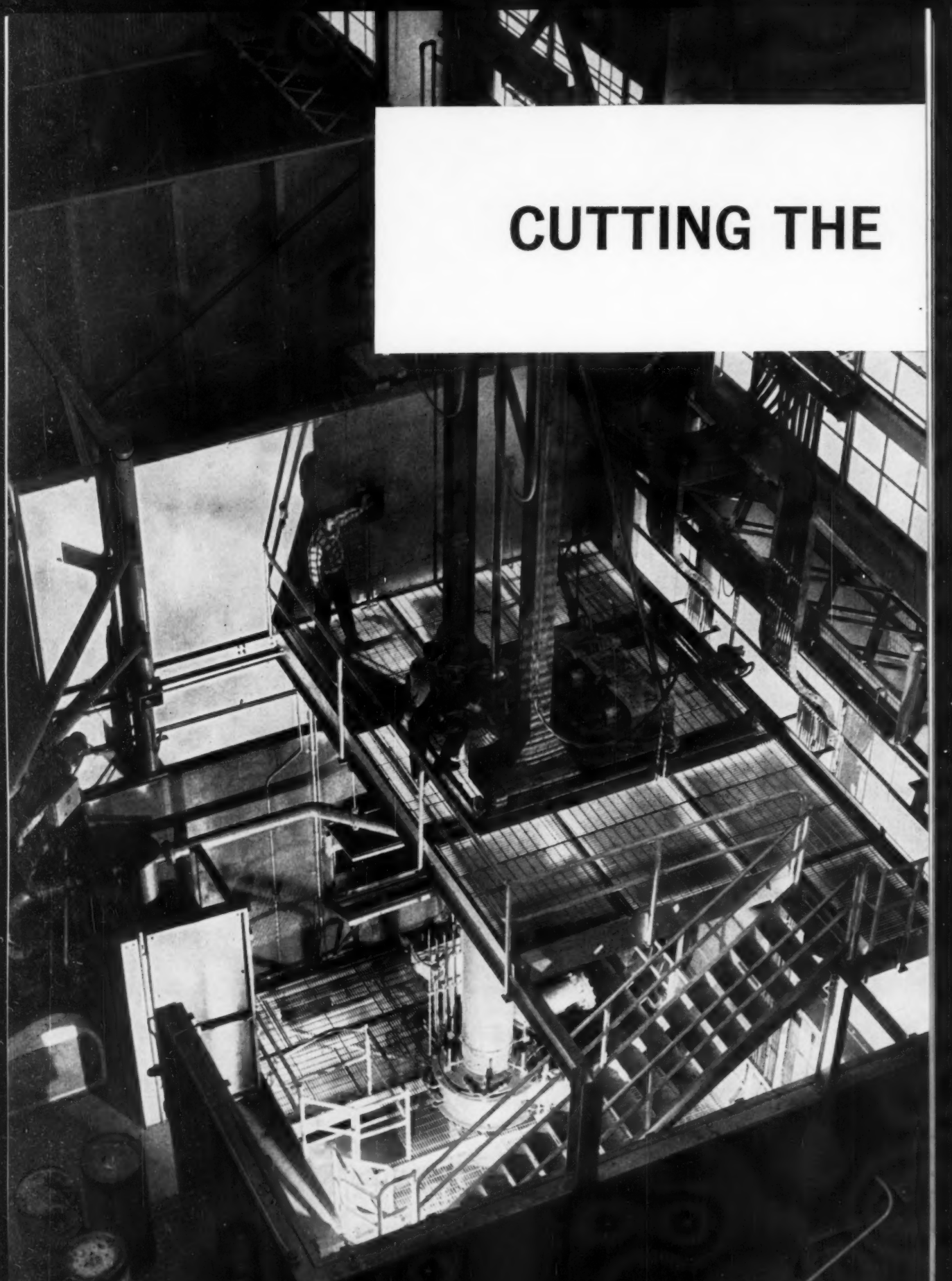
Lightweight—only 24 lbs per cubic foot

JOHNS-MANVILLE

AN INSULATION FOR EVERY COMMERCIAL AND INDUSTRIAL USE

JOHNS MANVILLE JM PRODUCTS

Circle 1501 on Page 48-B



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...with 20,000-pound heats of Republic Vacuum-Melted Metal

Processed into billets, sheets, bar, strip, or wire, vacuum arc melted metals are being delivered in quantity, on time, at reasonable cost.

To minimize the cost, Republic produces vacuum-melted metals in larger melts—4,000 to 20,000 pounds. Integrated facilities process 18- to 32-inch diameter ingots into a wider range of product sizes and conditions than ever before possible.

Republic's consumable electrode vacuum-melting process improves mechanical properties—tensile strength, ductility, fatigue life, and performance at high and low temperatures. Precise control reduces nonmetallic inclusions and harmful gases.

Our metallurgists will help you select and apply the vacuum-melted metal best suited to your requirements: *constructional alloy steel, high strength alloy steel, bearing steel, stainless steel, super alloy steel, titanium, or special carbon steel.* For information, contact your nearest Republic sales office or mail the coupon on the opposite page.

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Republic PH 15-7 MO* for missiles and aircraft offers high ultimate tensile strength with excellent mechanical properties to 1000°F. Republic 17-4 PH* for shafts, gears, pins and other components requires only a one-hour heat treatment at 900°F to develop its full strength (ultimate tensile strength to 200,000 psi). Republic 17-7 PH* for pressure tanks, bellows, springs, and other applications provides better corrosion resistance than the hardenable grades of chromium stainless. Send for PH Stainless Steel Booklet.

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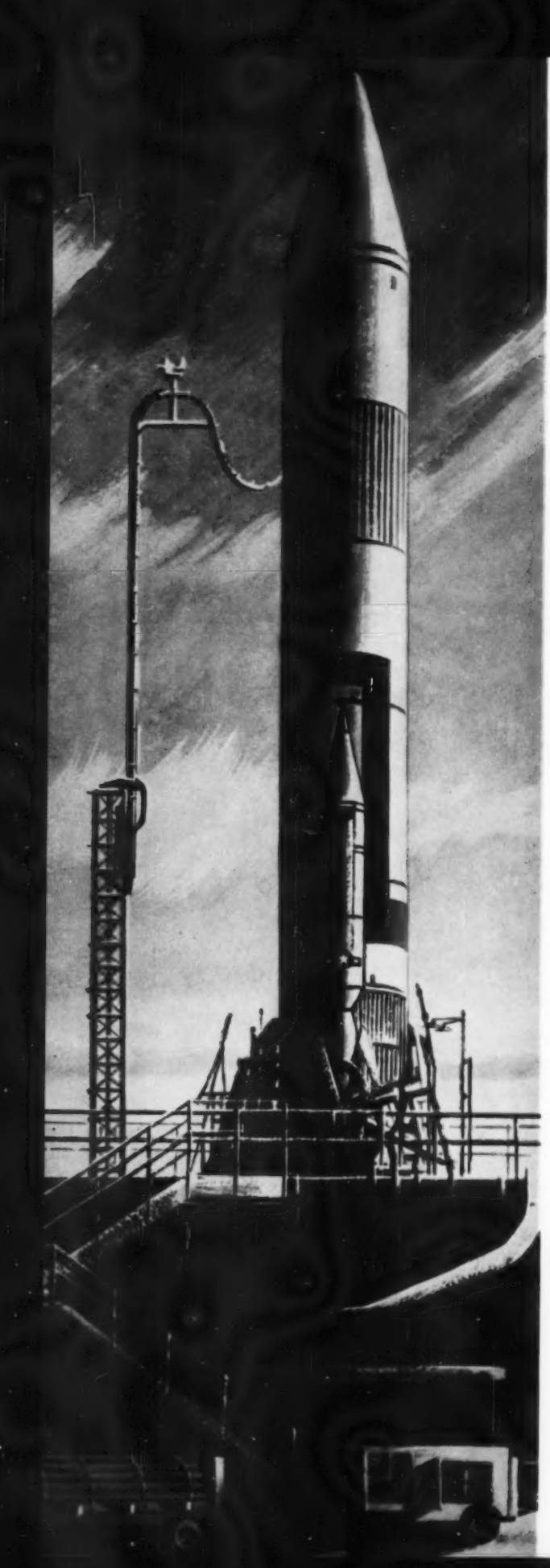

Metal Progress

Vol. 79, No. 4 April 1961

Selection of Metals for Use at Cryogenic Temperatures

*By A. HURLICH and J. F. WATSON**

Since the newer missiles and rockets will be powered by liquid oxygen (boiling point, −297° F.) and liquid hydrogen (boiling point, −423° F.), there is much interest in materials which will remain tough at such low temperatures. This article describes the cryogenic test facilities at Convair-Astronautics, and lists several of the aluminum, titanium, and stainless steel alloys which can be used for low-temperature applications. (Q-general, T24e, T2p, 2-63, 17-57; Al-b, Ti-b, SS)

WITHIN THE PAST FEW YEARS, the use of cryogenic fuels for missiles and space vehicles has stimulated interest in the low-temperature properties of metals. Many of today's missiles, such as Atlas, Titan, Thor and Jupiter, use liquid oxygen (boiling point, −297° F.) and JP-4, a petroleum derivative, as propellants. Upper stages of the newer space vehicles, such as Centaur (picture, left) and Saturn, are designed to use liquid

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Fig. 1 — Liquid Hydrogen Test Chamber. For experimental work, the stainless steel dewar flask, 23 in. deep by 6 in. I.D., is surrounded by a chamber for liquid nitrogen, and this chamber, in turn, is blanketed by foam insulation

oxygen-liquid hydrogen fuels, and forthcoming nuclear powered rockets will use liquid hydrogen as a working fluid. Thus, cryogenic propellants appear to be firmly established.

With this trend, the problems associated with materials for low temperatures are demanding increasingly widespread attention. At Convair-Astronautics we became intimately involved with such problems in developing the Centaur space vehicle, the first missile in this country to be fueled by a liquid oxygen-liquid hydrogen combination. Designed as an upper stage vehicle to be used with Atlas or Saturn boosters, the Centaur will perform various missions of space exploration. Since the materials used in these vehicles experience a variety of loading conditions at cryogenic temperatures during flight, their structural integrity demands that their mechanical properties be accurately measured down to -423° F., the boiling point of liquid hydrogen. In addition, the physical properties of nonstructural members (such as

thermal insulation) must be known in order to calculate such factors as propellant boil-off rates.

Equipment for Cryogenic Testing

To do the necessary research, we established two separate areas for testing materials in liquid hydrogen: an indoor setup for tensile, impact, and hardness tests of relatively small specimens, and an outdoor facility for tensile and fatigue tests of large specimens, many of which simulated actual weld joints in full-scale missile tanks.

Equipment for indoor testing was installed in a room with a floor area about 20 ft. square. This laboratory has several interesting features. Its gas-tight ceiling (sheathed with welded steel sheet) tapers upwards towards the center to three outlets topped by fans large enough to change the air in the room four times in a minute. Fan motors are explosion-proof as are all ceiling lights and electrical connections higher than 3 ft. above the floor.

Figure 1 shows a close-up of the liquid-hydrogen test chamber. It consists of a stainless steel dewar flask, surrounded by a jacket of liquid nitrogen which is, in turn, blanketed with polyurethane foam for insulation. The lower pull-rod of the tensile machine fits through a Teflon-sealed joint in the bottom of the flask, and the upper pull-rod fits into a removable stainless steel head. A special temperature-compensating extensometer, designed at Convair-Astronautics, also fits through a hole in the head to be clamped to the specimen which is totally immersed in the liquid hydrogen during testing. Stress-strain curves are automatically recorded. A specimen can be pulled to the yield point at a rate of 0.001 in. per in. per min. (or higher) and then tested to fracture. Less than 10 l. of liquid hydrogen is used per test, and the liquid nitrogen in the outer jacket does not require replenishment after the first fill. With this setup, 10 to 12 tensile specimens can be tested every 8 hr.

Since the test console of the tensile machine contains a large number of electrical connections that could not be made explosion-proof, a sheet steel room is constructed around it. Air is piped into this room at a slight positive pressure to insure against entry of hydrogen. All of the hydrogen gas leaving the test chamber is sucked directly out through a flexible steel hose leading to a ceiling vent and a suction fan. No more than 50 l. of liquid hydrogen is allowed in the room at one time.

Liquid nitrogen tests are also made indoors. For testing between −100° F. and room temperature, a steel chamber is available in which alcohol and dry ice can be used. In addition, a large insulated test chamber is available which can be fitted between the platens of the tensile machine. By circulating liquid and gaseous nitrogen through this chamber, it can be maintained at any desired test temperature between −320° F. and room temperature.

An over-all view of the outdoor testing area is shown in Fig. 2. Large specimens are tested in a wooden shed (shown in the background), the inside of which is illustrated by Fig. 3. In fatigue testing, the rate of loading is 6 cycles per min. With specimens fracturing in the range of 1000 to 5000 stress cycles, tests can be completed within 3 to 15 hr. (Most of this testing is performed at stress levels which range from 80 to 95% of yield strength values because design stresses are established as high as safety permits to minimize weights of missile structures.) To date, several hundred large welded joints have been fatigue tested at −320° F. and several dozen at −423° F.

Experimental Programs

A wide variety of sheet alloys including cold rolled austenitic stainless steels; aluminum, titanium, nickel, and cobalt-base alloys; and several heat treatable stainless steels have been tested at temperatures ranging down to −423° F. The alloys selected for study were chosen because they exhibited one or more of the following characteristics: high strength-to-density ratios; good toughness (resistance to brittle fracture); adequate weldability; retention of properties at cryogenic temperatures and at moderately high temperatures in the 700 to 1200° F. range; corrosion resistance; and good formability. To produce optimum strength levels, the alloys selected for study were either cold worked (cold rolled) or heat treated (age hardened, or quenched and tempered) to their highest strength levels commensurate with adequate toughness. In addition, since weldability is of prime importance in the fabrication of these vehicles, alloys were also tested in heliarc butt-welded configurations. Both smooth and notched test specimens of the alloys were tested at +78, −100, −320, and −423° F. in both longitudinal and transverse directions. Yield strength, tensile strength, elongation, and notched-to-unnotched tensile ratios (stress concentration factor, K_t =

Fig. 2 – Outdoor Area for Testing Large Specimens in Liquid Hydrogen. The operator's console is in the foreground. Also visible are large dewar flasks containing liquid hydrogen and liquid nitrogen

6.3) were determined for the metal, while only the tensile strengths of heliarc butt-welded joints were ascertained.

Notched tensile tests were included to evaluate toughness, a measure of resistance to catastrophic brittle fracture. Toughness is vitally important to the missile designer because missiles are subjected to many types of shock during firing. Missiles will also contain built-in stress concentrations of varying degrees of intensity which arise from welding defects, tool marks, assembly eccentricities, and other random defects. These conditions, all of which favor brittle failure, become even more severe at low temperatures because many materials are more apt to undergo brittle fracture at reduced temperatures.

The severest type of toughness test combines high strain rates, sharp notches, and low temperature, as typified by the Charpy V-notch test conducted at low temperature. However, we must use notched-to-unnotched tensile strength ratios as an index of toughness since almost all of the data are obtained on relatively thin sheet, and no fully reliable impact test has yet been devised for such material. Notched tensile test specimens allow use of sharp notches and low testing temperatures, but do not permit the high strain rates available in the CharpyV-notch impact test unless special types of tensile machines are used. The initial strain rate at the root of the notch is, however, greater than that encountered in tests of smooth tensile specimens because of the stress and strain concentration effect of the notches.

The stress concentration factor of 6.3 was selected because previous axial fatigue tests (on complex welded joints and large tanks made of Type 301 stainless steel) had exhibited good correlation with notched-to-unnotched tensile ratios obtained with this value of K_t over a range of temperatures from +78 to −423° F. Table I presents test data on cold worked stainless steels showing the correlation obtained between the notched-to-unnotched tensile ratios and the fatigue resistance of complex welded joints.

A large body of data, obtained as part of the Atlas and Centaur programs, showed that less acute notches (K_t of 2.5 to 3.0) did not distinguish very well between tough and brittle materials. In fact, some tests with this low

notch acuity on materials known to be brittle have yielded notched-to-unnotched tensile ratios of about unity. At the other extreme, however, stress concentration factors of 15 to 18, employed on a variety of materials, in general act to make all materials, including tough ones, appear to be brittle. Thus, K_t of 6.3 lying midway between these two extremes discriminated between tough and brittle materials and also correlated with service behavior. This, of course, is the ultimate proof of any laboratory test.

"Ductility" Is Not "Toughness"

A point of interest is that low notched-to-unnotched tensile ratios frequently occur at −423° F. where elongation values are relatively high. This simply demonstrates that elongation in the smooth tensile test does not measure toughness or notch sensitivity. Until recently, many investigators had been erroneously using the terms "ductility" and "toughness" interchangeably. Actually, they are two distinctly different properties.

Elongation, which is a measure of ductility, describes the ability of a smooth uniaxially stressed specimen to deform plastically when pulled in tension. Toughness, which may be evaluated by the Charpy V-notch impact test, notched-to-unnotched tensile strength ratios, and various tear tests, is a measure of resistance to fracture propagation under conditions of complex stress distributions, such as are provided by notches, rivet holes, inclusions, and sharp re-entrant corners. Combinations of impact loads, stress concentrations and low temperature form the severest type of toughness test, and are all present in a Charpy V-notch test conducted at low temperature.

A material may exhibit a large amount of ductility, as measured by elongation, and yet have very poor toughness, as measured by notched-to-unnotched tensile ratios, Charpy V-notch tests or crack propagation tests. For example, many of the carbon steels elongate as much as 15% in tensile tests at −320° F., but are as brittle as glass in notched-bar impact tests at this temperature. Conversely, some high-strength stainless steels may have elongations as low as 1 to 2% and yet be very tough at cryogenic temperatures.

Thus, to select a material the designer must rely on toughness data rather than ductility data. This is especially true in missile applications because all conditions favoring brittle failure are present: high strain rates, stress concentrations, high operating stresses, and low temperatures.

Tests on Stainless Steels

Cold rolled stainless steels exhibit an outstanding combination of properties which suit them for structural application in missiles and space vehicles powered by cryogenic propellants. These properties include good strength-to-density ratio, excellent toughness from −423 to +800° F., good weldability, good corrosion resistance, and excellent formability. Consider, for instance, Type 301, cold rolled about 60%. Now chosen as the skin material for the Atlas and Centaur vehicles, this steel has been subjected to an extremely wide variety of tests for

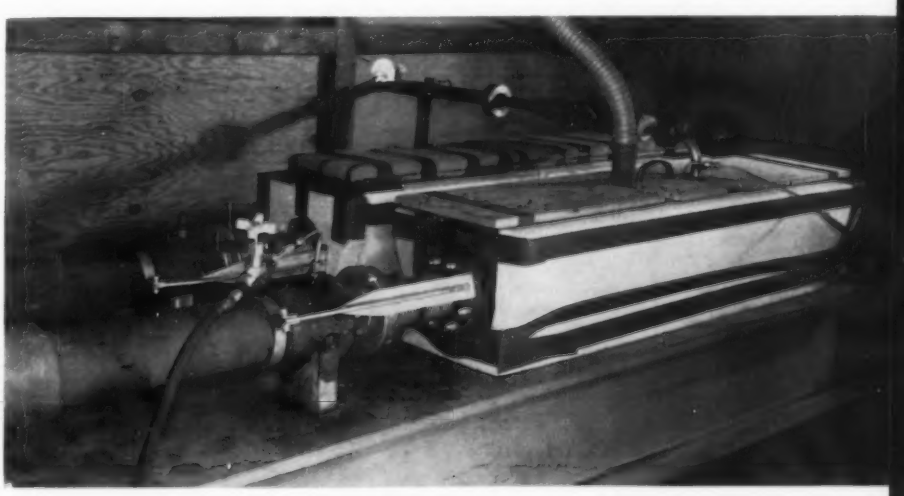

Fig. 3 — Chambers for Tensile and Fatigue Testing of Large Coupons in Liquid Nitrogen and Liquid Hydrogen. The specimens are immersed in the liquids, one end being fixed while the other end is pin-loaded to the end of a load cell projecting through the end of the test chamber

Table I – Correlation of Notched-to-Unnotched Tensile Ratios With Fatigue Properties*

	Test Temperature	Notched-to-Unnotched Tensile Ratio (K_t=6.3)		Cycles to Failure † 0 to 140,000 Psi.
		Longitudinal	Transverse	
Type 301,	+78° F.	1.05	0.97	934 (*a*)
60% cold rolled	−320	0.99	0.87	2671 (*a*)
	−423	0.92	0.68	633 (*a*)
Type 310,	+78	1.07	0.97	—
75% cold rolled	−320	1.11	1.07	1855 (*c*)
	−423	1.12	1.03	2000‡
Type 301-N,	+78	1.08	0.97	632 (*b*)
60% cold rolled	−320	0.84	0.80	327 (*b*)

*Tests were made on weld joints 3½ in. wide, 20 in. gage length, 38 in. over-all length. All sections: 0.020 in. thick.

†For fatigue tests, weld joints were axially loaded and unloaded between 0 and 140,000 psi. in tension at 6 cycles per min. Letter code indicates average of (*a*) three tests; (*b*) five tests; (*c*) two tests.

‡Test stopped after 2000 cycles. One small crack was evident in heat-affected zone of one of the resistance welds in outer row of spots. Estimated fatigue life: 3000 cycles.

mechanical and physical properties at temperatures ranging from −423 to 1000° F. These include strength, fatigue resistance, toughness, weldability tests (involving butt, lap, and spot welds), stress-corrosion tests, thermal conductivity tests and many others. This alloy, as of now, is being produced to specifications which require stringent tolerances for thickness, camber, flatness, and surface quality. Closer tolerances, which are produced by cold rolling in a Sendzimir mill, assure a more uniform product.

Type 301, extra full hard, exhibits a tensile strength which increases from about 220,000 psi. at +78° F. to about 330,000 psi. at −423° F., while the yield strength increases from about 200,000 psi. to 285,000 psi. over the same range. This type of steel can be applied on the basis of low-temperature properties when the structure is subjected to maximum loading only at low temperatures.

Where higher fatigue life for a given stress level is desired, a more stable steel (for example, one in which the austenite to martensite reaction does not occur) would be specified. Such an alloy is Type 310 corrosion resistant steel. When cold rolled 75%, this alloy has somewhat less strength at +78° F. than extra full hard Type 301 sheet. However, the increased strength of Type 310 at lower temperatures exceeds the room-temperature strength of Type 301. Thus, where the steel is stressed only at low temperature, Type 310 can be used without a weight penalty.

Further studies of austenite stability as influenced by chemical analysis were performed on Type 301-N steel (Type 301 with 0.10% N), cold rolled about 60%. This alloy has tensile and yield strengths about equal to those of Type 301, extra full hard. However, lower notched-to-unnotched tensile ratios at lower temperatures show that it is unsuited for cryogenic use.

So that the effect of structure on properties could be measured and evaluated, all of these studies of the 300 series stainless steels have been accompanied by thorough metallographic, X-ray diffraction, and magnetic examinations. Results show that Type 301, extra full hard (now in use on Atlas and Centaur vehicles), Type 304 ELC, 50% cold rolled or more, or Type 310, cold rolled 75%, would be excellent for liquid hydrogen tank skins of space vehicles.

Because of their good toughness at low temperature, low density, moderately high strength, and good weldability, aluminum alloys have been a favorite for cryogenic structures. These generalities do not apply to all aluminum alloys, of course, and each alloy class must be studied separately for use in aerospace vehicles.

The 5000 series aluminum alloys, which contain varying amounts of magnesium in solid solution, are noted for their excellent weldability and toughness at low temperatures. A high-magnesium aluminum alloy was used for liquid oxygen tanks on the German V-2 rocket and an alloy of that type is employed in the Saturn. In the latter, 5456-H343 aluminum is used. It contains about 5% magnesium in solid solution and is cold rolled a small amount. Similar alloys for earlier missiles such as Jupiter and Jupiter-C were 5052 and 5086, containing 3 and 4% magnesium, respectively.

Although these alloys are not as strong or as hard as 5456, they can be cold rolled to strengths comparable to those of 5456-H343 with much better low-temperature toughness, as measured by notched-to-unnotched tensile ratios. This avenue of alloy development is now being followed with promising results.

The 2000 series of aluminum alloys are the well-known age hardening alloys which contain copper as their major alloying constituent. These alloys, notably 2014-T6 and 2024-T4, have much higher tensile and yield strengths than do the 5000 series. For this reason they are much more attractive for airborne tanks (see Table II). However, since pressurized cryogenic fuel tanks require welded joints for pressure integrity, the weldability of these alloys becomes of major concern. Fusion welded joints of 2014-T6, for example, have always been regarded as marginal at best, because they exhibit poor ductility as measured by bend ductility tests. However, by designing around the problem with thickened weld joints, satisfactory structures have been produced. This type of design is typified by the Thor and Titan missiles, which employ 2014-T6 as a primary structural material. The base-metal properties of 2024-T4, 2014-T6, and 2219-T87 aluminum sheet are all acceptable at −423° F.

The 7000 series of aluminum alloys contain zinc, copper and magnesium. In the heat treated condition, they have the highest strengths of any aluminum alloys commercially available. Unfortunately, these high levels are accompanied by low resistance to brittle failure at cryogenic temperatures. For this reason no alloy in the 7000 series is recommended for liquid hydrogen service. (Only 7079-T6, in fact, is acceptable for use at −297° F., the temperature of liquid oxygen.)

Table II – Strength-to-Density Ratios and Notched-to-Unnotched Tensile Ratios for High-Strength Sheet Alloys at Cryogenic Temperatures

	Test Temperature	Strength-to-Density Ratio ($\times 10^{-6}$) Psi./Lb./Cu. In.		Notched-to-Unnotched Tensile Ratio (K_t=6.3)
		Tensile	Yield	
Type 301, 60% cold rolled	+78° F.	0.64	0.76	1.05
	−100	0.73	0.83	1.04
	−320	0.86	1.10	0.99
	−423	1.00	1.10	0.92
Type 301-N, 60% cold rolled	+78	0.63	0.71	1.08
	−320	0.80	0.91	0.84
	−423	0.96	1.03	0.79
Type 304 ELC, 50% cold rolled	+78	0.55	0.61	1.09
	−100	0.64	0.68	1.09
	−320	0.65	0.87	1.04
	−423	0.80	1.05	1.09
Type 310, 75% cold rolled	+78	0.55	0.62	1.07
	−100	—	—	—
	−320	0.74	0.84	1.11
	−423	0.88	0.97	1.12
5052H38 aluminum	+78	0.41	0.47	1.07
	−100	0.42	0.48	1.07
	−320	0.50	0.65	1.01
	−423	0.57	0.92	0.90
2014-T6 aluminum	+78	0.66	0.73	1.02
	−100	0.69	0.76	1.04
	−320	0.74	0.85	0.98
	−423	0.86	0.98	0.94
2024-T3 aluminum	+78	0.48	0.68	0.89
	−320	0.61	0.87	0.88
	−423	0.73	1.10	0.81
6061-T6 aluminum	+78	0.44	0.48	1.05
	−320	0.52	0.63	1.00
	−423	0.56	0.82	0.93
7178-T6 aluminum	78	0.83	0.90	1.02
	−100	0.88	0.75	0.81
	−320	0.99	1.06	0.54
	−423	1.11	1.23	0.51
A 110 AT titanium	+78	0.70	0.74	1.34
	−100	0.84	0.88	1.22
	−320	1.14	1.22	1.15
	−423	1.43	1.52	0.97
6,Al 4,V titanium, annealed	+78	0.76	0.88	1.06
	−100	0.81	1.07	0.93
	−320	1.13	1.36	0.89
	−423	1.38	1.55	0.71
"K" Monel, age hardened	+78	0.32	0.51	0.93
	−100	0.35	0.54	0.93
	−320	0.39	0.60	0.95
	−423	0.45	0.66	0.99

Again, the weldability problem severely limits the range of applicability of this alloy class.

The 5000 and 2000 series aluminum alloys will undoubtedly remain as primary structural materials in the forthcoming series of upper-stage

space vehicles. In addition to the advantages which have been listed, aluminum, by virtue of its low density, can be used in relatively thick sections. This is of major importance in stiffening compression-type structures since tank stiffness usually increases with the square of the wall thickness. Of the alloys with the same strength-to-density ratio, only magnesium and beryllium structures would exceed the stiffness of an aluminum structure, and neither of these metals is acceptable for structural applications at low temperatures.

Tests of Titanium Alloys

The titanium alloys, because of their outstanding strength-to-density ratios, good weldability, and excellent corrosion resistance, are of major interest for missile and space vehicles. This is best typified by the successful development and use of the 6 Al, 4 V titanium alloy in the helium pressurization bottles which form part of the pneumatics system of the Atlas missile. Because of their proximity to the rocket engines, the bottles are subjected to extreme vibrational loading. Thus, this application requires a high order of resistance to brittle fracture. For this application, incidentally, the 6 Al, 4 V alloy is solution quenched and aged to a tensile strength in the range of 155,000 to 165,000 psi.

For over a year, titanium sheet alloys have been tested at temperatures ranging down to −423° F. (They include A 110 AT; 6 Al, 4V; B 120 VCA; 6 Al, 4 Zr, 1 V; 7 Al, 12 Zr; and RS 140.) Data from the tests on A 110 AT (given in Table II) prove that it exhibits excellent notched-to-unnotched strength ratios, especially at the lower temperatures. This alloy was studied because of its excellent toughness at room temperature, as well as its excellent strength-to-density characteristics and its good weldability.

No generalities can be made concerning the behavior of hexagonal close-packed alloys at cryogenic temperatures. Although magnesium and zinc (both hcp.) appear to be brittle at low temperatures, pure titanium and many of its alloys are very tough at the subzero range. The 6 Al, 4 V titanium alloy, for example, has given excellent service at −320° F.

With decreasing temperatures, A 110 AT is characterized by large increases in both tensile strength and yield strength along with very small decreases in elongation. Because many designs are based on yield strength rather than tensile strength, the large increase in yield strength is of prime importance in missile design. Such alloys can be used to advantage in structures which are highly stressed only at low temperatures. Since this titanium alloy displays an excellent notched-to-unnotched tensile ratio down to −423° F., it appears to be a promising one for cryogenic applications.

Even when welded, A 110 AT is as strong as the parent metal because it is used in the annealed condition and does not respond to heat treatment. Thus, in tensile tests of heliarc butt-welded joints, fracture occurred in the base metal rather than in the weld metal because the weld had been roll planished, thus increasing its strength slightly by cold work. The two titanium alloys that show the most promise for cryogenic applications are the A 110 AT alloy in the form of sheet (useful down to −423° F.), and the 6 Al, 4 V alloy in the form of sheet and high-strength heat treated forgings (useful down to −320° F.).

Work to Come

In the coming years activity will be focused on the development of alloys (such as the alpha titanium group) which have outstanding strength-to-density characteristics at cryogenic temperatures. In addition to A 110 AT (5 Al, 2.5 Sn) now in production, newer alloys such as 5-5-5 Al-Zr-Sn, 8-1-1 Al-Mo-V, and 8-2-1 Al-Cb-Ta will be thoroughly evaluated in both the base metal and welded joint configurations. As for aluminum-base alloys, research will be directed toward high-purity alloys such as 7275, which can be processed by techniques such as controlled atmosphere melting and ultrasonic treatment during ingot solidification. Developments in the austenitic stainless steels will be directed toward studying effects of vacuum melting, and stress-relief heat treatments.

Other work in this area will concern the useful temperature limits of certain promising alloys. For example, the 6 Al, 4 V titanium alloy has been used successfully at −320° F., but appears to be seriously embrittled at −423° F. Also, though stainless steels such as AM 350, AM 355 and A-286 have shown promise at −320° F., they display decreasing toughness at −423° F. Other alloys may possess useful properties for specific applications at moderately low temperature as a result of special heat treatment or other special processing.

In short, though we have solved many problems, still more remain. The march towards perfection never ends.

Estimating Critical Ranges in Heat Treatment of Steels

*By R. A. GRANGE**

Formulas are proposed for calculating the upper and lower critical temperatures from the chemical compositions of medium carbon and low-alloy steels. Mean deviations of measured values from calculated values are between 5% and 6%. (N8, 2-60, CN, AY)

WHEN HEAT TREATING STEEL, it is often helpful and sometimes essential to know the upper and lower critical temperatures to within a few degrees. Since it is somewhat difficult to measure these two temperatures in a particular steel, the metallurgist usually has recourse to tabulations of Ac_1 and Ac_3 temperatures which appear in various handbooks. However, there is a drawback to this procedure. Though such tables include values representative of each standard type of steel, they do not reveal the variation to be expected from differences in composition among individual heats of each grade. And it is also helpful to be able to estimate reliably the lower and the upper critical temperatures from the composition of *any* heat of steel, whether it is a standard type or not.

Because these temperatures depend primarily upon chemical composition of the steel, we have, over a period of years, determined the upper and the lower limits of austenite formation for a great number of heats representing over 50 different compositions. After collecting and statistically analyzing these data to reveal the quantitative effect of each of the principal alloying elements, we have been able to combine the individual effects in the form of empirical formulas.

Some Notes Concerning Terms

Before discussing these formulas, we should consider the question of terminology. When the lower and upper limits of austenite formation in hypoeutectoid steels are measured by continuously heating at some specified rate, they are called "Ac_1" and "Ac_3", respectively. In either instance, the temperature which is determined varies with the rate of heating. It is lower with slower heating rate, the closest approach to equilibrium being attained when the steel is heated at the slowest possible rate.

A less tedious method, which yields essentially the same value, consists of holding specimens at each of a series of constant temperatures for varying periods of time up to several hours (or at least until doubling the holding time causes no appreciable change in the amount of austenite formed), and then quenching to room temperature. The lower and upper limits of austenite formation determined by this isothermal technique have usually been designated "Ae_1" and "Ae_3", subscripts "1" and "3" referring to the A_1 and A_3 lines of the iron-carbon phase diagram.

However, there are ambiguities. In steel which contains three or more elements, the A_1 can become a three-phase field. Furthermore the "e" implies true equilibrium conditions which are rarely if ever attained in steel of commercial purity. For these reasons, we propose to use the symbols "A_s" and "A_f" in this article. In accord with the well-established use of "M_s" and "M_f" (to denote the temperature range of martensite formation), "A_s" is defined as the temperature at which a barely detectable

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amount of austenite forms during prolonged holding at constant temperature and "A_f" is the temperature at which the last trace of *ferrite* transforms to austenite on prolonged isothermal holding.* Practically speaking, therefore, A_s constitutes a "ceiling" for tempering and A_f a "floor" for austenitizing hypoeutectoid steel.

Calculating the Formula

From data representing the effects of manganese, silicon, nickel, chromium and molybdenum, we developed formulas for estimating the upper and lower critical temperatures. To do this, we first plotted, for each element, the percentage amounts of alloys against the resulting A_s and A_f temperatures. The curves which we obtained showed that both temperatures changed a given amount with each additional percentage point of alloying element. (For example, the A_s temperature dropped about 25° F. with each percent of manganese; therefore, the formula for calculating the upper critical temperature includes the factor, "$-25 \times$ % Mn".)

Of course, this method requires a straight-line relationship, and the quantitative effect of each of these elements on either A_s or A_f is usually not directly proportional to its weight percentage. However, over a limited range for each element, only a small error results from assuming direct proportionality. The combined effect of phosphorus, sulphur and residual elements is assumed to be small; hence it can be neglected without appreciable error. Furthermore, molybdenum, at least in percentages less than 0.50, had no effect upon either A_s or A_f. Consequently, neither formula requires a factor for molybdenum.

On this basis, A_s can be related to the chemical composition of a steel as follows:

$$A_s(^\circ F.) = 1333 - (25 \times \% \text{ Mn}) + (40 \times \% \text{ Si}) - (26 \times \% \text{ Ni}) + (42 \times \% \text{ Cr})$$

Unlike A_s, the upper critical temperature is markedly influenced by carbon content, the effect of carbon being indicated by the slope of the A_3 line of the iron-carbon phase diagram. Over the 0.3 to 0.6% C range, A_f is lowered very nearly in direct proportion to the weight percentage of carbon. This enables us to express the effect of carbon — in steels containing 0.3 to 0.6% C, of course — in simple mathematical terms. When this effect is combined

*It would be desirable from the fundamental standpoint to define A_f as the minimum temperature for total austenite formation. However, this leads to the experimental difficulty of measuring the exact temperature at which the last trace of carbide dissolves in austenite, a test that is difficult, if not impossible, to do. Thus, A_f as defined above has little or no significance in respect to the heat treatment of hypereutectoid steels.

Table I — Comparison of Measured and Calculated A_s and A_f Temperatures

A.I.S.I. Number	C	Mn	Si	Ni	Cr	Mo	A_s		A_f	
							Measured	Calculated	Measured	Calculated
C 1031	0.35	0.37	0.21	—	—	—	1330° F.	1330° F.	1470° F.	1465° F.
C 1045	0.47	0.57	0.20	—	—	—	1330	1325	1420	1420
C 1065	0.63	0.87	0.22	—	—	—	1325	1320	1355	1360
1335	0.35	1.85	0.19	—	—	—	1295	1295	1430	1425
1340	0.42	1.58	0.30	—	—	—	1300	1305	1420	1420
2340	0.37	0.68	0.21	3.41	—	—	1225	1235	1350	1340
3140	0.38	0.72	0.21	1.32	0.49	—	1305	1310	1390	1400
4037	0.35	0.80	0.24	—	—	0.25	1315	1320	1465	1455
4047	0.48	0.94	0.16	—	—	0.25	1315	1315	1405	1405
4130	0.33	0.53	0.27	—	0.90	0.18	1355	1370	1465	1470
4140	0.37	0.77	0.15	—	0.98	0.21	1365	1360	1445	1445
4150	0.44	0.95	0.23	—	0.93	0.21	1350	1355	1425	1420
4340	0.42	0.78	0.24	1.79	0.80	0.33	1300	1310	1375	1375
4640	0.36	0.63	0.19	1.84	—	0.23	1280	1275	1395	1395
5140	0.42	0.68	0.16	—	0.93	—	1360	1360	1425	1445
8630	0.30	0.80	0.29	0.54	0.56	0.21	1330	1335	1450	1460
8650	0.50	0.77	0.22	0.60	0.51	0.22	1325	1330	1385	1385
8742	0.44	0.90	0.25	0.44	0.54	0.22	1320	1330	1435	1410
86 B 50*	0.50	0.77	0.23	0.60	0.50	0.21	1325	1330	1395	1390

*Possible effect of 0.0016% B was neglected in the calculation.

with the effects of individual alloying elements, the following formula results:

$$A_f(^\circ F.) = 1570 - (323 \times \% C) - (25 \times \% Mn) + (80 \times \% Si) - (32 \times \% Ni) - (3 \times \% Cr)$$

Some Limitations of the Formulas

Since both formulas are based upon the assumption that the effect of additional elements upon A_s and A_f is directly proportional to the weight percentage and also that the individual effects are algebraically additive in steel containing several alloying elements, the formulas are easy to calculate. However, they require the following compositional limitations: 0.3 to 0.6% C; 0 to 2% Mn; 0 to 1% Si; 0 to 3.5% Ni; 0 to 1.5% Cr; and 0 to 0.5% Mo. Fortunately, this composition range covers many of the standard A.I.S.I. low-alloy steels, several of which are listed in Table I. In this table, the measured and calculated values were rounded off to the nearest 5° F. in accordance with the probable experimental error to be expected in measurement. This is usually permissible because, as can be seen in the table, greater precision is not justified.

Although the calculated values of A_s differ from the measured values by as much as 15° F. in one instance, the mean deviation is only 5° F. with about as many calculated values on the high side as on the low side. Calculated values of A_f differ from the measured values by as much as 25° F. with a mean deviation of 6° F. Both critical temperatures, especially A_f, are influenced by segregation which is always present to at least some extent in commercial steels. Unfortunately, this factor, which may explain why the calculated value occasionally differs considerably from the measured value, cannot be readily evaluated.

When we tried to extend these formulas to steel compositions outside the recommended range, our calculated results became more unreliable with increasing alloy content. For reasons already discussed, it does not seem possible to develop one simple formula which would be satisfactory for all types of ferritic steel. Within the specified composition limits, however, these empirical formulas appear to be sufficiently reliable to be useful in planning heat treatments.

Zirconium-Copper Alloy. . . High Strength and Conductivity

*By A. E. MOREDOCK and D. K. FOX**

Copper with 0.15% Zr added combines good electrical conductivity (96% I.A.C.S. after aging) with moderate strengths and hardnesses up to 660° F. Uses: All types of electrical apparatus which need electrical and mechanical properties throughout a range of operating temperatures. (P15g, Q-general, T1, 17-57; Cu-b, Zr)

ELECTRICAL EQUIPMENT is constantly being asked to withstand higher operating stresses and temperatures. Zirconium-copper, a new alloy with high electrical conductivity combined with moderately high strength and hardness up to 350° C. (660° F.), fills a long-existing need. In the electrical industry, alloy choice has for many years been limited where high electrical and thermal conductivity are required along with mechanical properties appreciably

*Materials Engineering Department, Westinghouse Electric Corp., Pittsburgh.

Table I – Electrical Properties of Some Wrought Copper Alloys

Property	Zirconium-Copper	Tough Pitch Copper	Cadmium-Copper	Beryllium-Copper	Chromium-Copper	Copper-Nickel-Silicon Alloy
Electrical conductivity, % I.A.C.S.	96 (aged)	100	87	55 (aged)	85 (aged)	35
Modulus of elasticity, psi. $\times 10^6$	18.7	16.5	16.0	18.0	17.0	20.0
Electrical resistivity, 20° C., ohms per circular mil-ft.	10.9	10.4	11.9	20.7	12.7	32.3

better than those obtainable with copper. The same circumstance exists for applications requiring high electrical conductivity where resistance to softening on heating is important.

Most alloys fail in one or the other of these two requirements. For example, silver-bearing coppers have 100% I.A.C.S.* electrical conductivity together with correspondingly high thermal conductivity. But they will soften during soldering and brazing. Further, mechanical properties are low, approaching those of pure copper. On the other hand, chromium-copper (99.4% Cu, 0.6% Cr) resists softening very well, both under long-time exposure up to 400° C. (750° F.) and during properly controlled brazing cycles as high as 700° C. (1300° F.). However, the electrical conductivity is only 85% I.A.C.S.

Other alloys, widely used for conductors and having desirable mechanical properties, but lacking in optimum electrical conductivity or strength to varying degrees, include beryllium-copper (2.3% Co, 0.35% Be) with about 55% electrical conductivity, cadmium-copper (1% Cd) with about 87% conductivity, and copper-nickel-silicon alloy (2.0% Ni, 0.6% Si) with about 35% conductivity.

Table II – Effect of Elevated Temperatures on Transverse and Longitudinal Tensile Properties of Zr-Cu Alloy Bar

Temperature	Tensile Strength	Yield Strength (0.2% Offset)	Elongation in 2 In.
	Longitudinal Specimens		
Room temperature	47,000 psi.	41,000 psi.	38%
204° C. (400° F.)	40,000	37,000	33
371 (700)	35,000	34,000	30
	Transverse Specimens		
Room temperature	50,000 psi.	47,000 psi.	35%
204° C. (400° F.)	44,000	40,000	33
371 (700)	39,000	38,000	30

Table III – Effect of Elevated Temperatures on Some Copper Alloys

Temperature	Zirconium-Copper*	Tough Pitch Copper (Hard)	Chromium-Copper
	Tensile Strength		
Room temperature	72,000 psi.	50,000 psi.	70,000 psi.
350° C. (662° F.)	54,000	18,000	—
400 (752)	51,600	15,000	42,900
450 (842)	48,000	11,000	—
500 (932)	39,400	8,500	34,300
	Elongation		
Room temperature	12.0%	10.0%	25.0%
350° C. (662° F.)	15.5	47.0	—
400 (752)	15.0	53.0	1.0
450 (842)	21.0	57.0	—
500 (932)	19.5	58.0	3.0

*Solution treated, cold worked 85%, aged 1 hr. at 375° C. (670° F.) Courtesy American Metal Climax, Inc.

Zirconium-copper, a precipitation hardening alloy with 0.15% Zr and 99.85% Cu, is made with oxygen-free copper. Heat treatment consists of two steps – a solution treatment at 900° C. (1650° F.), followed by a rapid water quench, and age hardening at 400° C. (750° F.) for about 2 hr., the time being somewhat dependent on previous mechanical history. To obtain the best mechanical properties, the alloy is cold worked extensively after solution treatment. The amount of cold work permissible will, of course, depend upon the necessary secondary fabricating operations such as bending, forming, and pressworking. Some properties of zirconium-copper are shown in Table I and are compared with those of other alloys.

*International Annealed Copper Standard. (100% is equal to the conductivity of pure copper.)

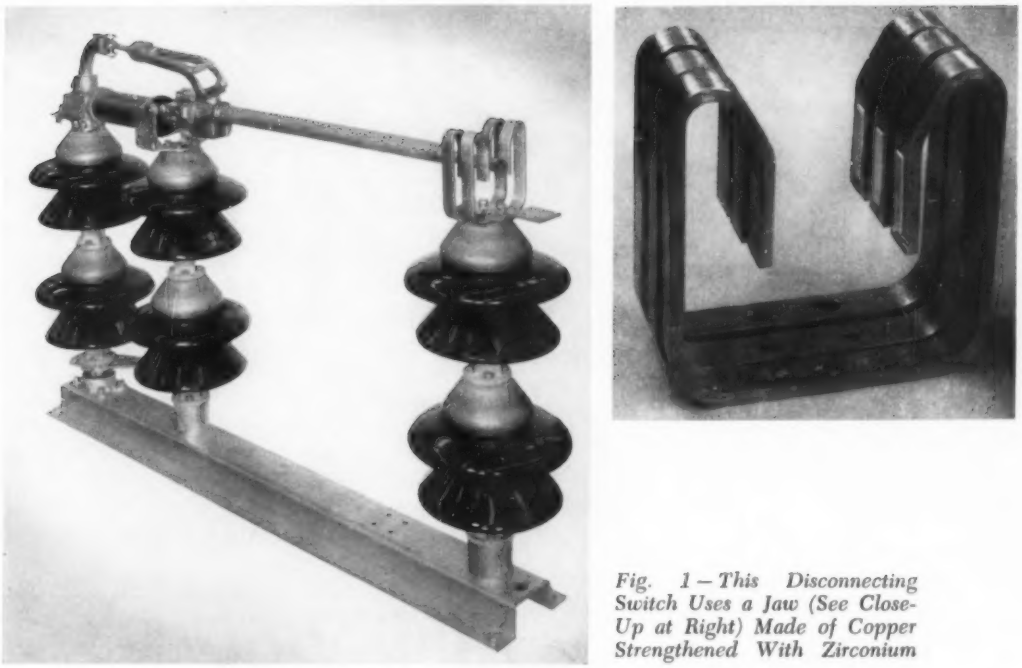


Fig. 1 — This Disconnecting Switch Uses a Jaw (See Close-Up at Right) Made of Copper Strengthened With Zirconium

Zirconium-copper, as Table II shows, has tensile and yield strengths which are somewhat better in the transverse direction than in the longitudinal direction. This is important for commutator bar applications where stresses are transverse to the drawing direction. The tensile strength of zirconium-copper is appreciably greater than hard drawn copper in the range from room temperature to 500° C. (930° F.) as Table III shows. In comparison with chromium-copper, the tensile strength of zirconium-copper is also somewhat greater at elevated temperatures. Furthermore, chromium-copper exhibits a much greater decrease in elongation, and, of course, does not have as high electrical conductivity.

Two interesting features of zirconium-copper in the aged condition are its high modulus of elasticity (18.7×10^6 psi.) and excellent electrical conductivity (96% I.A.C.S.). Both characteristics make the alloy attractive where stiffness and good electrical properties are both needed.

One of the ever-present problems in brazing of copper, chromium-copper and beryllium-copper is softening at the joint and in the adjacent heat-affected area. In zirconium-copper, there is a marked decrease in this tendency to soften compared to tough pitch copper and silver-bearing copper, its electrical counterparts. When zirconium-copper is compared with chromium-copper and beryllium-copper, the difference is not so marked, but it is still in favor of the zirconium-copper alloy.

Potential Applications

Wrought zirconium-copper can probably be used for applications which require an electrical conductivity closely approaching that of copper and where mechanical properties similar to those of chromium-copper are desired. The high elastic modulus will enable the alloy to be used for springs and other structural parts which must be conductors as well.

The alloy could be used for windings for all types of electrical apparatus where operating temperatures greater than those now in vogue are encountered. It is also suitable for springs and other structural parts which conduct current, motor commutators (particularly for aircraft and missile applications), commutator necks and risers on electrical equipment where increased fatigue strength is desired after brazing or soldering, and slips and terminals which must carry current and where the use of copper requires "backing-up" with steel springs.

A New Concept in Heating

Principles of the Fluid Bed

*By J. D. STAUFFER and C. O. PEDERSEN**

When a thick layer of small particles of refractory (silica sand, for example) is heated in a container and subjected to a blast of gas from the bottom, it will billow, boil, and flow much like a fluid. This characteristic is the basis for the "fluid-bed" furnace, a new type of heating device which is reported to heat parts rapidly and cleanly. (J-general, B15q)

A NEW TYPE OF FURNACE – one which uses a solid (rather than the conventional liquid or gas) for a heat transfer medium – evolved from work conducted at General Electric's industrial heating department laboratories. Based on the fluid-bed principle (first used in catalyst beds for petroleum processing), this new system has several advantages over conventional methods.

As a starter, one may well ask "What is the fluid bed and how does it work?" A fluid bed results when a gas is passed upward through a bed of small solid particles at a rate fast enough to lift these particles and give them a violent turbulent motion. It is termed "fluid bed" because it gives the same "feel" or sensation to the human body as immersion in a normal fluid, it exhibits a hydrostatic head, and it can be pumped or transported from one container to another while under the influence of pressure drop.

To explain the action further, look at Fig. 1,

*Development Engineers, Industrial Heating Dept., General Electric Co., Shelbyville, Ind.

left. When the gas is forced *upward* (through small holes in a supporting plate), there are two forces acting to raise the particles: the buoyancy of the gas and the aerodynamic drag. When the flow through the bed is increased to the point where these two upward forces equal the particle weight, the particles will be lifted since they are not confined at the top of the bed.

In actual practice, the particles are not only lifted, but also swirl rapidly with a high degree of turbulence. As more and more gas is passed upward through the bed, it will expand to fill a greater volume of the container. This expansion, illustrated by Fig. 1, right, is necessary to satisfy the force balance between particle weight, gas buoyancy, and the aerodynamic drag on the particle. In fact, the velocity can be increased until particles are blown away from the bed, but this condition must be avoided. Otherwise, sand particles will be lost and the fluid bed will continually decrease in size.

Heating properties of the fluid bed can be adjusted through a wide range because there are many parameters which can be varied. The major ones are: *(a)* particle properties – size, shape, bulk density, and absolute density; *(b)* properties of the gas used to fluidize the bed – density, viscosity, heat capacity, and thermal conductivity; *(c)* system properties – flow of gas through the bed, total weight of the particles in a given bed, cross section and shape of the bed container, and the type of permeable plate used to support the particles.

Characteristics of the Fluid Bed

One of the most attractive properties of the fluid bed is the high rate with which heat can flow from the bed of particles to an object immersed in it. In fact, coefficients of heat transfer in the order of 70 to 130 Btu. per hr.-sq.ft.-° F. are not uncommon. This rate of heat flow is two to ten times higher than that provided by normal convection or radiation. Furthermore, the rate of heat transfer in the full bed is relatively independent of the emissivity of the object which is immersed and the temperature level.

High turbulence is another important feature adding to the effectiveness of the fluid bed. This turbulence, with the resulting thorough mixing, effectively eliminates gradients, and provides a uniform temperature throughout the bed.

The Basic Fluid-Bed Furnace

Basically, the fluid-bed furnace is simple in construction. The container consists of an insulated casing, while the hearth is constructed of a permeable heat resistant material – a permeable refractory such as firebrick can be used. The fluidizing atmosphere flows from a chamber – called a "plenum" – directly beneath the hearth. Refractory particles (silica or alumina sand, for instance) are poured onto the permeable hearth to be fluidized by the gas. The primary heat sources – they can be electric heating elements or radiant tubes – are immersed in the bed, the temperature being controlled by conventional instrumentation. For heating, parts are immersed in the turbulent mass of particles by any of several suitable handling devices.

Some of the Theory

To maintain a bed of particles in the fluidized state by a gas atmosphere, the following force balance must be satisfied:

Buoyant Force+Aerodynamic Drag Force=
Weight of Particles

(However, in gas fluidized systems, the buoyant force is usually negligible – this simplifies calculation.) The aerodynamic drag on the particle, then, must be equal to the weight of the particle, and this drag shows up as a pressure drop in the fluidizing gas. As a practical example, let us fluidize 100 lb. of refractory particles in a bed having a hearth area of 4 sq.ft. The gas pressure drop through the bed would be

$$\frac{100 \text{ lb.}}{4 \text{ sq.ft.}} = 25 \frac{\text{lb.}}{\text{sq.ft.}}$$

This value will be independent of the type of atmosphere used.

As might be expected, the minimum velocity required to fluidize a bed of particles depends on the properties of the particles and fluidizing gas. In general, the velocity for minimum fluidization rises with particle diameter and drops with temperature. Often it is desirable to use a velocity greater than the minimum required; this extra gas flow expands the bed to provide a greater depth which might be needed for larger parts. (As an example, Fig. 2 shows the changes in volume which result when a range of velocities is employed for several sizes of alumina sand.) Generally speaking, greater turbulence and larger heat transfer coefficients can be achieved by use of velocities consider-

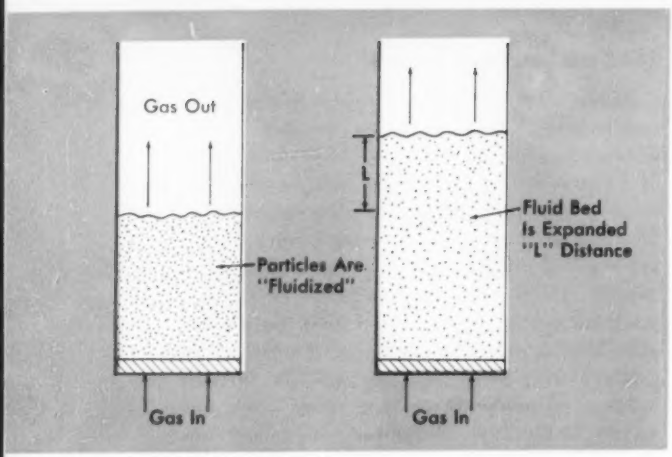


Fig. 1 – Principle of the Fluid Bed Furnace. Gas flows upward through the permeable base fast enough to lift the small particles of refractory material – silica sand can be used, for example – to lift them and give them a violent turbulent motion. Though the particles are actually solid, the bed has the characteristics of a liquid

ably in excess of the minimum required.* Care must be taken, however, to insure that the velocities used are not so high that particles are thrown from the bed.

Heat Transfer Characteristics

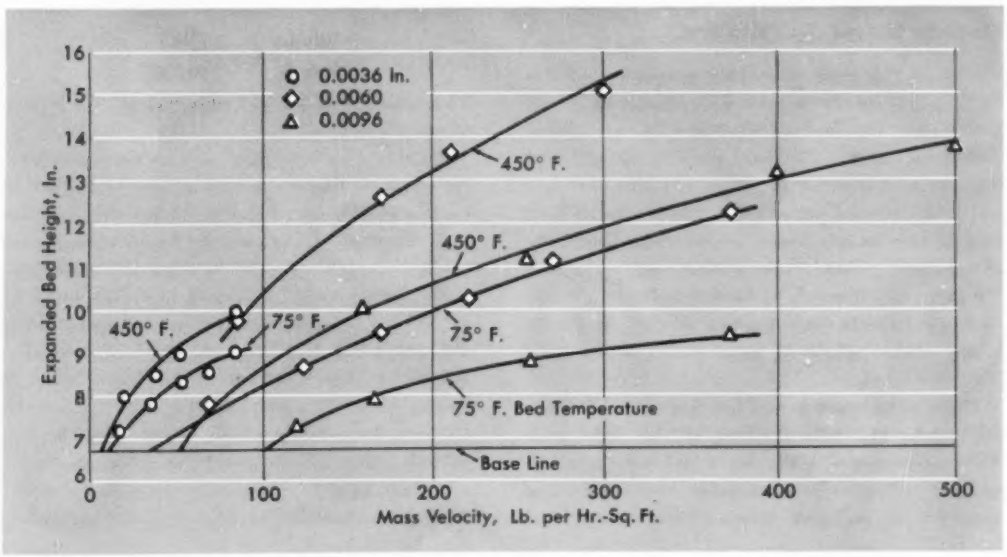
By changing of basic bed parameters, heat transfer rates can be varied within a fairly wide range. Thus, it is possible to tailor the heat transfer coefficient to meet specific requirements. As the rate of gas flow increases, heat transfer increases until a maximum is reached. Then, at high rates of gas flow it will begin to drop. The change in heat transfer coefficients here would be around 20 to 30%, and this would correspond to a manyfold increase in the mass flow rate.

In general, decreasing the particle size will increase heat transfer rate. Other variables such as bed depth, the position of the object in the bed, and the shape of the object have some slight effects on the heat transfer rates, but these are small in comparison to the effects that were previously shown.

The mechanism by which heat is transferred in fluidized beds is not well understood. Though several different viewpoints have been expressed in the literature, most attempts at describing heat transfer theoretically have not been successful. It is common practice, therefore, to use equations obtained by correlating experimental data to predict heat transfer rates in fluidized beds.

*An interesting point: If the fluidized particles were not present and the same superficial gas velocity was used, one could expect a heat transfer coefficient on the order of 2 to 5 Btu. per hr.-sq.ft.-°F. Thus, adding the particles in effect increases the heat transfer rates 20 to 30 times.

Fig. 2 – How the Volume of a Fluid Bed Changes With Gas Velocity, Temperature, and Particle Size. With no gas flow, bed height was 6.75 in.



Actually, for illustrating the advantages of fluidized beds for metallurgical heat treatment, specific examples are more suitable. Suppose, for example, we compare the time-temperature curves during heat-up for the same object in a fluidized bed and in a conventional radiation furnace. Figure 3 shows such a comparison of curves obtained in heating a copper bar in a fluidized bed and in a conventional radiation furnace. (The two curves shown for the radiation furnace depict the copper in oxidized and unoxidized conditions.) Obviously, the heat transfer rate in the fluidized bed is much greater than it is in the conventional radiation furnace. Therefore, the time needed to heat to a given temperature is much shorter in the fluidized bed. (It should be re-emphasized here that since the heating mechanism in a fluidized bed is basically a convection phenomena, it is relatively independent of object emissivity, unlike the heating effect produced in a radiation furnace.)

As for other features, there is no size limitation on the objects which can be heated in a fluidized bed, but large parts must have a fairly high thermal conductivity to take advantage of the high heat transfer rates which are available without developing internal temperature differences. For example, aluminum parts with dimensions greater than about 12 in., though they will heat up in a considerably shorter time in the fluidized bed than they would have in a conventional furnace, might experience some temperature nonuniformity during heating. A comparable dimension for steel parts would be about 2 in.

As another characteristic advantage, the fluidized particles do not collect on the work surface as do other mediums with high heat transfer rates (such as molten salt or metal). Thus, no subsequent cleaning is needed. Of equal importance, the heat treater has a method which can give him a very precise cycle between two temperature levels, since the heat transfer coefficient needed can be obtained by proper selection of particles and fluidizing gas.

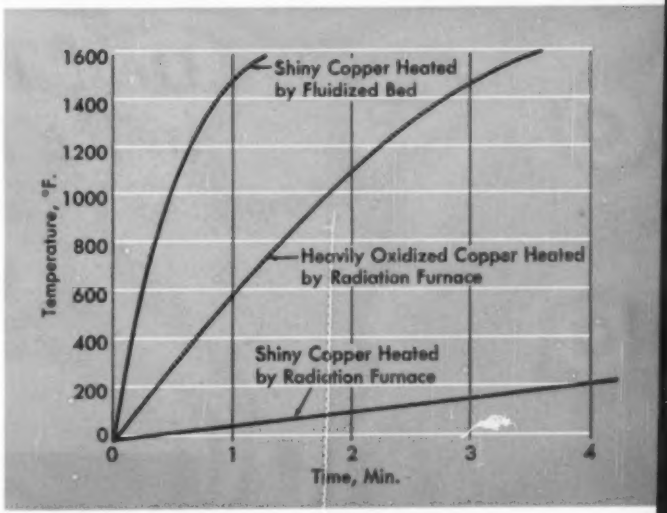


Fig. 3 – Comparison of Heating Curves for a Fluid Bed and a Radiation Furnace. Note that the fluid bed heats the copper bar (1 in. diameter by 6 in. long) much more rapidly

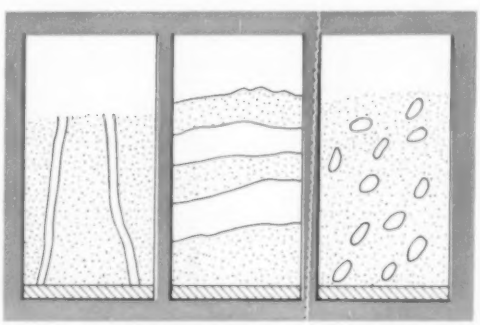


Fig. 4 – Channeling (Left), Slugging (Center) and Bubbling (Right) Are Three Types of Poor Fluidization Which Can Result from Mismatch of Particle Size and Gas. Each fluid bed system must be carefully planned for its subsequent use before being put into operation

Care Is Needed

It must be emphasized that the performance of a fluid-bed furnace cannot be predicted unless all the parameters present have been carefully considered. If the fluidizing atmosphere and particles are improperly selected or matched, undesirable bed characteristics, such as shown in Fig. 4, can develop to destroy much of the effectiveness of heat transfer. Since there are little data available on fluid bed systems for heating in the 1500 to 2000° F. range, we carry on a continuing program to optimize the design of fluid-bed furnace components, establish the most efficient furnace shapes, and determine the maximum transfer coefficients obtainable for various particle-gas combinations. With proper selection of components and predictability of performance, the fluid-bed furnace can become a major aid to the heat treater in industry.

Heat Treating in the Fluid-Bed Furnace

*By CHARLES BENNETT and CHARLES JUNG**

Fig. 1 — Engineers Heating Aluminum in 1½-Ton Fluid Bed. The small particles of refractory sand do not cling to or contaminate the part; therefore, there is no cleaning problem

The fluid-bed furnace is rapidly achieving production status at Boeing Airplane Co. Among other successful applications, it has been used in austenitizing intricate parts of alloy steel and for removing residual stresses from aluminum parts. (J-general, B15q)

THE FLUID-BED FURNACE OFFERS close temperature control, rapid uniform heating and cooling, and temperature ranges needed to handle the heat treating problems which have been incurred by the advent of such superalloys and refractory metals as René 41, Inconel "X", molybdenum and columbium. Furthermore, this new heating technique is now achieving production status in the processing of conventional steels and aluminum alloys.

During the course of its development, several simple fluid-bed systems for heat treating and quenching were built, the main effort being dictated by the need for immediate, practical solutions to specific problems in heat treating new metals. This article discusses some of the details of fluid beds and practical applications of the technique.

To begin with, the general principle of fluid beds (discussed in the article on p. 78) is well known. Adaptation of the method to production heat treating has several fundamental advantages, one of which is uniformity of temperature. This is achieved by the turbulent action in the bed which allows the small particles of sand (they act as heat reservoirs and carriers) to absorb heat from a localized heat source, and release it uniformly and rapidly throughout the bed. Because of the turbulence, the temperature can be maintained at a remarkably constant value. Our tests have shown that such a bed, when stabilized at a given temperature, was uniform throughout its volume within $\pm 2^{\circ}$ F. from -50 to 2000° F.

Fluid Beds Are Economical

From the standpoint of aircraft production, fluid beds are relatively economical, being simple to erect and operate. Beds may be constructed in production shops using standard equipment and materials, and, being portable, can be easily moved wherever they are needed. For operation, attachments are made to a source

*Manufacturing Development Engineers, Aero-Space Div., Boeing Airplane Co., Seattle, Wash.

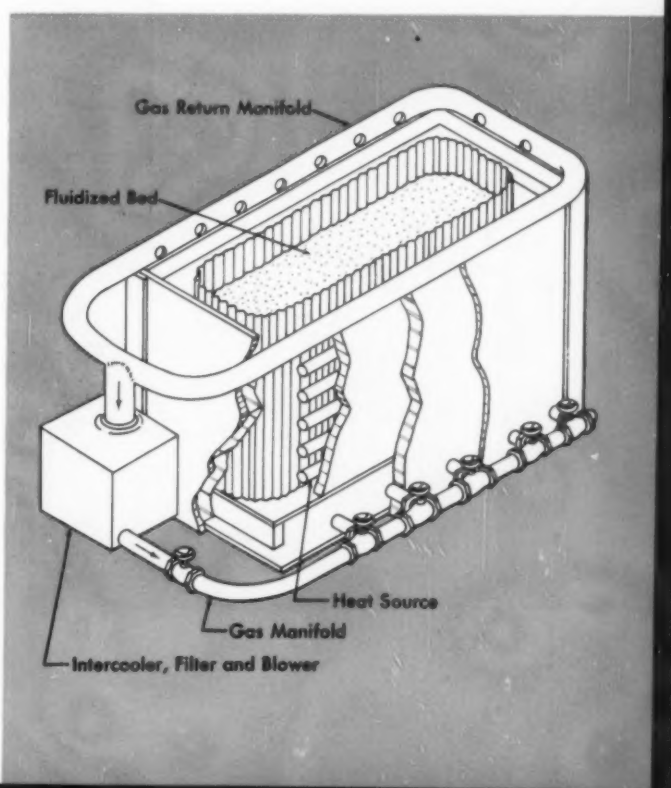


Fig. 2 – Diagram of Proposed Fluidized Bed Furnace. As is apparent, the bed of olivine sand (−80 to +150 mesh) is heated from the outside by electric resistance elements. The fluidizing gas enters the bottom and is recycled through the manifold at the top. This unit is much like that shown in Fig. 1 which was used in obtaining the data shown in Fig. 4, 5, and 6

Table I – Characteristics of Sand for Fluid Beds

Type	Particle Size*								Weight, Lb./ Cu.Ft.	Specific Heat/ Cal./G. 1°C.	Maximum Temperature	Screened Cost Per Lb.
	+60	+80	+100	+150	+200	+270	+325	−325				
Olivine sand 100 grade	Trace	1.1%	13.8%	37.3%	26.2%	13.8%	3.6%	4.2%	96.0	0.14	2500° F.	$0.07
Ione grog† −60 +100	0.4%	47.6	22.4	25.1	2.9	0.7	0.2	0.7	79.3	0.12	2700	0.22
Olivine sand 70 grade	41.3	25.2	11.0	9.0	5.2	3.0	5.3	—	105.6	0.14	2200	0.105
Zirconium oxide −60 +100, as received	—	2.9	6.7	22.8	27.2	29.5	2.6	9.3	92.8	0.103	4895	6.00
Tabular alumina −60 +100	0.4	55.0	20.5	20.1	1.6	0.6	0.2	0.6	79.3	0.174	3400	0.85
Pure silica	16.7	59.4	7.0	13.8	2.7	0.3	0.1	—	85.4	0.143	3125	0.10
Albany 00‡	11.0	18.3	1.1	20.2	20.8	15.1	1.0	12.5	83.2	0.160	1200	0.10

* Percentages refer to the weight of total material sample retained on a given screen after passing through a screen one size larger. The size desired for best fluidization is +80 to +150.

†Ione grog is calcine clay from the Ione pits in California.

‡Albany sand is standard foundry sand, high in iron content.

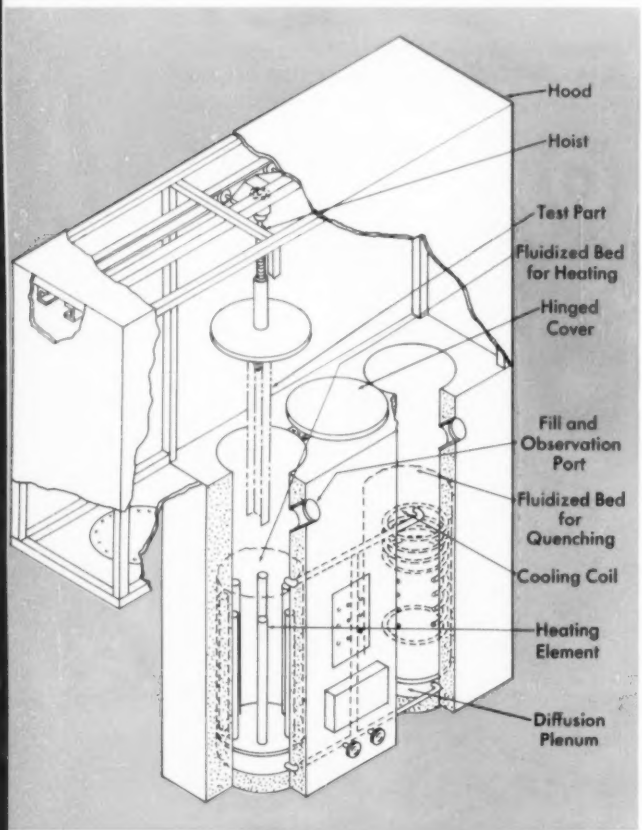


Fig. 3 – Design of a Fluidized Bed System for Heating and Quenching in a Controlled Atmosphere. The remote-controlled hoist transfers the part from the heating bed to the cooling bed without exposure to outside air

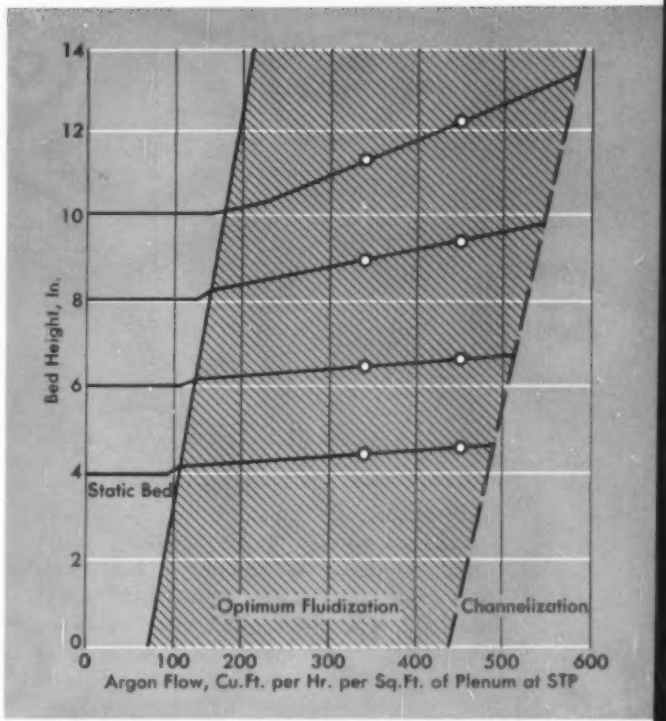
of fuel, standard temperature sensing and recording equipment, and cylinders of compressed gas (or a blower) for the fluidizing gas. Since fluid beds do not require hearths, as do air furnaces, size is generally dictated by the work zone required to handle the largest workpiece. In fact, fluid-bed furnaces may be constructed to any size, large or small, and they can also be built shallow or relatively deep to fit specific shop areas.

Many Methods for Heating Beds

The bed can be heated in many ways; electricity, gas or oil are all usable. Induction heat may be used, or radiant heat may be introduced at the top of the bed. Gas may be burned directly in the bed. If oil is used, heat can be transmitted to the bed from a tube inserted in the bed or by impinging the flame against heat-conducting walls of the fluid-bed container. Table I lists some of the refractory sands which can be employed in the bed.

As another advantage, specific atmospheres can be provided by simply changing the com-

Fig. 4 – Graph Showing Expansion of Bed With Increase in Gas Flow. "Plenum" refers to the gas chamber under the bed, and "channelization" refers to the incidence of channels which can occur in beds with excessive gas flow. The "optimum" condition shown here will change with alterations in refractory sand and gases



position of the fluidizing gas. Various compositions and mixtures of refractory particles allow the selection of a fluidizing medium compatible with nearly any heat treatment cycle and temperature requirement. In quenching, parts may be rapidly cooled through the critical temperature range; temperature drop is not retarded by a vapor phase, a feature of most liquid quenches.

In addition to being rapid and precise, temperature control is relatively simple. Temperatures can be reduced by turning off the heat source and allowing the fluidizing gas to quench the bed. An increase in temperature involves only a simple adjustment of control to introduce enough heat to bring the bed to temperature.

Fluidized beds offer a fail-safe feature that protects metal parts under heat treatment (as well as the unit) in the event that either the heat source or gas blowing equipment fail. In these eventualities, the bed either does not heat or does not fluidize. If heat fails, the bed starts to cool slowly, and if fluidizing equipment fails, the particle mass settles around the immersed part. Neither is a major problem. To place the bed in an inactive state, heat and fluidizing gas are turned off. Since the bed does not freeze up, the refractory lining and fluidizing particles cool slowly, unchanged.

Our Development Work

The fluid beds built at Boeing range in size from small laboratory units to the prototype production model (Fig. 1) which is much like that diagramed in Fig. 2. A projected design for a fluid bed with controlled atmosphere is shown in Fig. 3. Experimental work has, since the beginning, been coupled with production

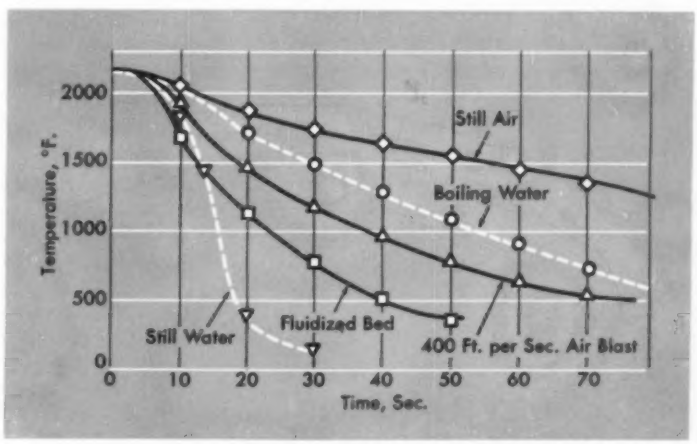


Fig. 5 – Quenching Curves for a ¾-In. Metal Ball. The curve for the fluid bed was obtained by Boeing engineers; the others were reproduced from an article in the Journal *of Institute of Metals, 1958-59, Vol. 87, p. 296. When quenched in the fluid bed, the ball cooled from over 2000° F. to below 500° F. in 20 sec.*

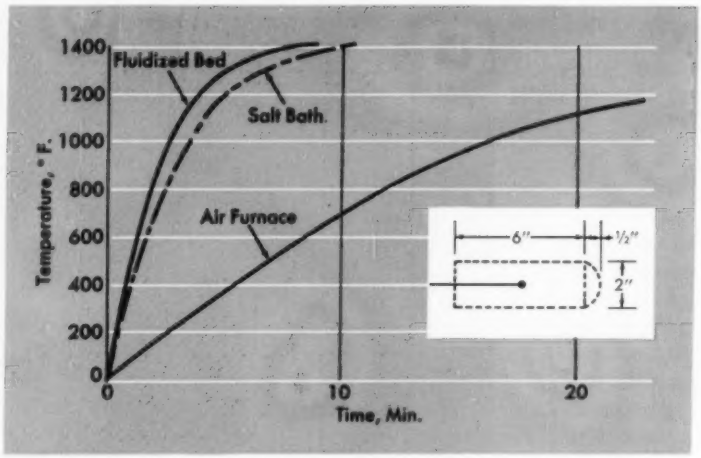


Fig. 6 – Heat-Up Curves for Fluid Bed, Salt Bath, and Air Furnace. Inset shows test part; it was made of Type 321 steel and weighed 5 lb.

heat treatment problems. (Some experimental results are shown in Fig. 4, 5 and 6.)

In one production example, a problem exists in the hot straightening of machined and heat treated forgings from which warp has to be removed at not over 350° F. Air furnaces take too long to heat the parts. A hot oil bath is used, but the problems of fire hazard, removal of hot oil from parts and oil splatter are present. A prototype fluidized bed is now being used in the shop concerned to gather research data in connection with this problem.

Austempering Alloy Steel

Another production application involved the successful austempering of a 36-in. long segment of an alloy steel part (A.I.S.I. 4330-M). Because of the complicated shape (see Fig. 7), conventional quenching and tempering resulted in excessive warpage in the close-tolerance parts. With fluid beds being used for austempering, however, warpage in 65% of the segment was less than 0.001 in. and maximum warpage was less than 0.005 in.

Austempering by fluid bed differed slightly from conventional austempering. First, the part was austenitized at 1600° F. in a conventional air furnace. It was then quenched in a fluid bed held at 600° F. When the part and bed reached a steady-state condition, the heat source was turned off. With the halting of fluidization, the sand settled around the part to insulate it. After holding for 2 hr., the part was removed. In this instance, the insulating property of the bed maintained the part at 600° F. – an operating economy not obtainable in other types of furnaces.

Inverse Quenching to Remove Stress

A current research problem involves the use of a fluid bed as a rapid-heat facility in inverse quenching studies. (The process is used to re-

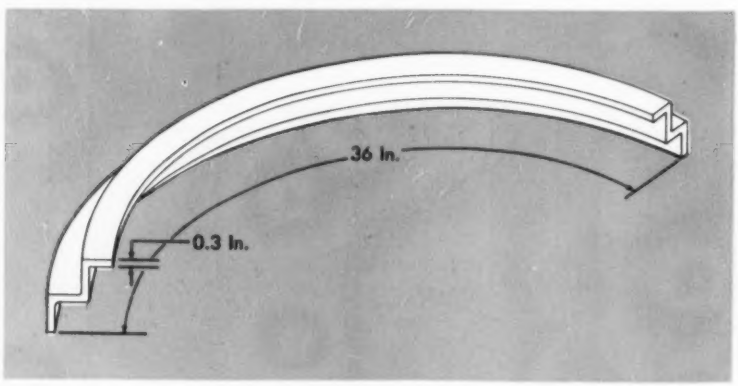


Fig. 7 – This Ring Segment of 4330-M Steel was Austempered in a Fluid Bed With Little Warpage. Conventional heat treatment caused excessive warpage

move residual stresses in heat treated items; its use on aluminum parts was described in *Metal Progress**.) Investigation into the novel process with a fluid bed has shown that not only aluminum alloys but René 41 and titanium can be thermally shocked by the rapid heat transfer produced when a cold part is put into a hot bed. The residual stresses which are thus removed result in the reduction or elimination of warpage during machining; shelf life is also better.

One part thus treated was an A-360 casting that required machining to close tolerances. It had previously been machined from solid bar stock, and considerable savings were anticipated from use of a newly designed die casting. After several lots were finish machined, however, all of them warped out of tolerance after one day on the shelf and were rejected. As-cast parts were then inverse quenched in a fluid bed from room temperature to 350° F. After machining and shelf life tests, all passed inspection. In stress removal from parts made of alloys such as René 41 and titanium, the parts were inverse quenched to the highest temperature not detrimental to the mechanical properties. These tests also proved that inverse-quenched parts warped less after machining than did unprocessed parts.

A portable fluid bed has also taken a role in the development of explosive forming at elevated temperatures. In this application, hot sand at 1400° F. is used to heat the parts. The bed is housed in a temporary structure and is gas heated; a blast of air from the compressor then fluidizes the bed. Figure 8 shows hot sand (1400° F.) being transferred to the explosive forming die.

Fluid Beds Are Safer

In the field of safety engineering, the use of fluid beds for heat treating deserves mention. They reduce the hazard from water that is spilled into the fluidizing medium. Instead of a violent reaction, water turns to steam which escapes with the fluidizing gas. Also, there is no splash hazard from inserting or removing parts, and the beds are fail-safe. Surface water and moisture on parts is likewise not hazardous (unless, of course, moisture is locked inside a part as might occur in a porous casting).

*"Reduction of Warpage . . . by the Thermo-mechanical Method", by H. N. Hill, R. S. Barker and L. A. Willey, *Metal Progress*, August 1959, p. 73.

Fig. 8 – Sand Heated in a Fluid Bed to 1400° F. Is Transferred to a Die Used in Explosive Forming. In the next step, this sand is again fluidized to transfer heat to the part being formed

We at Boeing who have participated in the development of fluid-bed furnaces are enthusiastic about the possibilities of the new heat treating technique. It is, at the least, a new and refreshing approach to the solution of some traditional heat treating problems as well as many newer problems. To those who have worked with it, the fluid bed is a dynamic thing with a character all its own. Since it often seems to defy the rules of logic and common sense, additional research and development work is necessary to assure optimum design and operation. One of the oft-quoted expressions among Boeing heat treat specialists who have designed, built and used the fluid bed furnaces is, "Give it lots of loving care – and when it's working, don't change a thing".

How to Use Magnetic-Particle Methods

*By L. B. STRADER and D. W. COLLINS**

Though useful only for detecting defects at and near the surfaces of ferromagnetic materials (iron, nickel, cobalt and their alloys), this method of nondestructive testing is widely used. There are various types of equipment and techniques with which parts of almost any shape and size can be tested rapidly and accurately. (S13j)

MAGNETIC-PARTICLE TESTING IS USEFUL in locating defects in metals that are attracted by a magnet. As a rule, users of the method can generally detect all surface discontinuities on ferromagnetic material (iron, nickel, cobalt and their alloys) and, under certain conditions, subsurface discontinuities as well. A wide variety of defects can be detected. These include surface defects such as quenching cracks, thermal cracks, surface seams, forging laps, grinding checks, surface inclusions, surface cracks in welds, and fatigue cracks, and subsurface defects comprising subsurface seams, subsurface inclusions, porosity, blow holes, cavities, laminations, and welding defects (including subsurface shrinkage and slag inclusions).

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A third category of defects is sometimes mentioned, but it really is a combination of the two. For example, a surface seam might be covered for part of its length; it then becomes a subsurface seam.

Types of Defects

There are several types of defects commonly uncovered by this method of inspection:

- **Primary discontinuities** include shrink cavities, blow holes, nonmetallic inclusions and segregates. Each type originates in the primary form in which the molten metal is shaped (for instance, in ingots or castings) and will usually persist in some form throughout all subsequent operations.
- **Fabricating discontinuities** include laps, bursts, cracks and seams. They appear during fabrication to a semifinished form (by forging, rolling, drawing, twisting, bending, forming, welding or other method).

• **Processing discontinuities** are generally cracks resulting from such processes as heat treating, grinding, etching, pickling and machining. They occur while the part is being processed into its final shape and condition.

• **Service discontinuities** are usually cracks which appear during service stressing. They will normally be one of two general types: fatigue cracks originating from successive applications of stress, or static cracks originating from a single application or relatively few applications of high stress. Service cracks are frequently initiated at primary, fabricating, or processing discontinuities.

Surfaces Must Be Clean

Before any part is subjected to magnetic-particle testing, it must be free from oil, sand, loose rust, loose scale or other "dirt". Further, welded parts must be free from all flux. The part can be cleaned by a pressure blast, brushing or other suitable method.

This "dirt" has many effects. Oil on a surface, for example, will hold dry powder or will contaminate a wet bath and shorten its useful life. If the inspection is attempted on rough or scaly surfaces, indications can be difficult to interpret because of mechanical trapping of the powder. When indications seem to result from surface contaminants, they should be removed by grinding or other cleaning methods and the part should be retested. This will help the inspector determine if actual discontinuities are present. In checking welds, cleanliness is especially important since any residual flux will trap the powder; this could eventually lead to unnecessary repair.

A Little Bit of Theory

Before discussing methods for testing, it would be well to cover some theory. To begin with, defects in metal interrupt the continuity of the solid mass, and in a magnetized mass of material, they will cut across the lines of force. Polarity is produced at the interruption, creating magnetic poles on each side of the discontinuity. This new magnetic field will attract and hold the fine magnetic particles, forming a bridge across the discontinuity. The resulting indications (as Fig. 2 shows) will outline the size, shape and extent of the defect.

The strength of the force field is determined by the flux density and the chemical composition and shape of the object being tested. A high flux density can be produced in soft iron

Fig. 1 – Part Being Magnetized and Sprayed to Reveal Longitudinal Defects. The hoop at the left produces longitudinal lines of force when activated; it is used when the defects to be found are at a right angle to the shaft of the test part

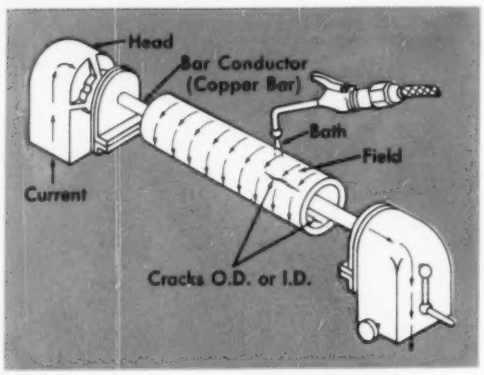

Fig. 2 – To Locate Longitudinal Defects in a Tube, Current Is Passed Through a Central Conductor. When the magnetic particles (usually suspended in an oil emulsion) flow over the tube, they collect around the defect to outline its size and shape

with a relatively low magnetizing force, but hardened steels require a higher magnetizing force for the same flux density. This is also true for cast iron, nickel and cobalt.

Test Techniques

Magnetic-particle inspection can be discussed under two categories: the method of magnetizing, and the technique used in applying the particles. Looking at the various magnetizing methods, we must first decide the type of current to use – a-c. or d-c. In deciding this, we should have an idea of the type of defect being sought: surface or subsurface. An alternating current is chosen when the anticipated defects are of the surface variety (grinding cracks, fatigue cracks and the like). When subsurface defects* are to be detected, direct cufrent should be chosen.

*"At what depth can a subsurface defect be detected?" is a question which always raises a lot of controversy. One large equipment manufacturer states that subsurface defects can be located down to ⅝ in. below the surface. At Westinghouse, a reasonable degree of consistency has been obtained from 3/16 to ¼ in. below the surface. In one instance, a sand pocket about 8 in. long by ¾ in. deep by ½ in. wide and lying about ½ in. below the surface was detected. (Direct current was employed in testing this casting.)

However, many factors determine the depth to which magnetic-particle testing can be called reliable. Some of them are size of section under test, size of defect, and position of defect in relation to the section in which it is contained.

The current can be applied in three ways: residual, continuous and flash. In the first, residual, the particles are applied after the magnetizing force is removed; for continuous application, the particles are applied when the magnetizing force is applied; and in flash, a high initial value of current is applied, then reduced to the preselected steady value. The flash (or "surge") method is used when high values of current are desired but cannot be maintained because of technical limitations.

Direction of Magnetization

Magnetization can be either longitudinal or circular depending on the expected orientation of the defect. For longitudinal magnetization, a current is passed through a coil which rings the part being magnetized. Maintenance men find this method, which will detect cracks at right angles to the length of the part, useful for locating fatigue cracks. For circular magnetization, the current can be passed through the part itself (see Fig. 1), or through a conductor that passes through a hole in a tubular type of part as Fig. 2 shows. Prods can also be used (see Fig. 3) if the part is too large to put between the electrodes of the machine.

Magnitude of Current

At this point, the question as to how much current to use should be asked. One general rule that can be applied is this: Use a value of current that will insure clear indications. However, too much magnetization will decrease the mobility of the particles – and this can cloud any indications that may form. (This is caused by the particles standing on end parallel to the lines of force of the external field.) Also, spurious indications (from scratches or conditions frequently associated with a banded microstructure) may appear.

As for prod magnetization, one convenient rule of thumb is, "For each inch of spacing between the prods, 100 amp. is necessary to create a satisfactory field".

Applying the Particles

The indicating particles can be applied in two manners – wet or dry. In the wet method, the particles are carried in either a suitable oil or in water. Both types are available in powder form with suitable wetting agents; they need only to be mixed in the correct quantity in the appropriate liquid. It is important that the

powders are initially mixed in the correct quantity, and that the bath is properly checked to maintain the correct percentage of powder during use. In fact, bath strength should be checked daily to insure uniform results. At the same time, it is good practice to make sure the bath is clean. Standard laboratory equipment with adequate instructions is available for checking these wet baths.

Wet powders, which are available in red, black or fluorescent types, are applied by pouring over the part, spraying, or immersing the part in the suspension. The method is usually most convenient for inspecting small, irregularly shaped parts, and when there are numerous parts to check. It is the most sensitive for fine surface cracks but is generally not suitable for subsurface defects. When fluorescent particles are used, irregular shapes can be scanned more quickly, indications in difficult locations can be easily detected, and there is less possibility of missing them due to human error.

One word of caution: Parts must be cleaned promptly and thoroughly after testing is finished. If this is not done, the powder will dry on the part, and its removal is next to impossible. Some plants that use the wet method find it helpful to add a small quantity of a rust-inhibiting oil to the bath; this aids the cleaning operation and keeps the test pieces from rusting.

Dry Method

In the dry method, dry magnetic powders, available in red, black and gray to provide different contrasts, are applied by shaking them from a muslin bag or a special shaker can, spraying from a rubber bulb, or using a mechanical powder blower. The last method is most convenient. After application, the excess powder is

Fig. 3 – Prods Are Used When the Part Is Too Large to be Handled in the Conventional Manner. This high-pressure, outer turbine cylinder weighs about 60,000 lb.; the chalk lines guide the inspector in checking all of the vital areas of the casting

removed with a gentle air stream. Adequate lighting is also necessary for easy observation of the indications.

The dry method is used for large castings, forgings and large fabricated parts and is reported to be more sensitive in locating deep-lying defects. (Though this latter statement may be controversial, it is generally accepted as being correct.) It is also used when flowing or spraying the particles on the work part is not convenient.

Demagnetization Is Often Needed

Demagnetization of the part after the test is often necessary. In fact, it is essential if the part is to go into an aircraft in a location where it will affect a magnetic compass, if the part is a bearing (or bearing housing) that may pick up particles that may later damage the bearing, if the part will be machined later where chips or particles may adhere to the tool or the part, or if adhering particles may interfere with cleaning operations.

Usually, three methods are used to demagnetize a part. It can be slowly removed from the field of a coil energized with an alternating current. Another method is to reduce an a-c. energizing force slowly while the part is held stationary with respect to the coil. A third method, which is probably the best, is to reverse and reduce in small increments a magnetizing direct current until a very low value is reached. This method has the advantage of eliminating the skin effect associated with alternating current.

A point to remember: Keep the axis of the work part pointed east and west. Otherwise, a component of the earth's magnetic field will show up as a residual field in the part. It should be noted that complete demagnetization is impossible. Where demagnetization is required, an attempt should be made to reach a stable minimum value.

Nonrelevant Indications Can Mislead

False or nonrelevant indications which sometimes plague the inspector may be due to any one of several factors. For example, powder lines can form at the roots of threads when using the dry method, or at the edge of the liquid when using the wet method. Also, indications may appear at the junction of two metals of different permeability, at the boundary of a weld and the base metal or in conjunction with a banded microstructure. Cold working, because of machining or some other reason, will often give an indication if there is an abrupt change in permeability.

"Magnetic writing" is an indication caused by local poles being formed when a magnetized part, or cables carrying current, come in contact with a test piece prior to testing. Flow lines (often from forging or rolling) will show on some types of steel when the part is subjected to magnetization far beyond that normally used to locate discontinuities.

An experienced operator can usually detect a false indication and discount it. However, with less-experienced operators or in certain test situations, additional tests may be needed to determine whether or not the indication corresponds to a real flaw in the test object.

Cost — a Major Consideration

Since cost is always a big factor in any manufacturing operation, we must also ask, "What will magnetic-particle testing cost my company, division or department?"

The actual cost of magnetic-particle inspection, since it will vary considerably among manufacturers (depending on the size of the parts and the volume of production), may range from 1/10 cent to 10 cents or more per part. In fact, the original equipment can cost from $150 to over $10,000. However, before purchasing any equipment, your inspection problem should be carefully evaluated and a decision made as to the type and size of equipment needed for your particular operation.

Despite the high initial expenditure, the the first cost of the equipment may be absorbed in a very short time because defective parts can be eliminated from production lines before money is spent and time wasted in processing them. Another more or less psychological advantage can also appear. Because there will be fewer rejections by the customer, his goodwill can be gained by assurance of satisfactory quality.

To sum up, magnetic-particle testing has a definite place in the nondestructive testing field and should be considered whenever ferromagnetic materials have to be inspected for defects. For those who need such testing, a broad line of magnetic-particle equipment is available, ranging from small and portable sets to large devices capable of sustained operation at high currents.

Improved Fuel Elements[*]

Pursuing the major objectives of our national reactor-development program – so industry can build large nuclear power plants by 1968 which will operate competitively with conventional plants in areas of high-cost fossil fuel – we have found that the central problem is to get the most power from a reactor core for the longest time at the lowest over-all cost. The composition, design and manufacture of the fuel element is a major factor in this problem.

Most of our operating power reactors, ashore and afloat, use the pressurized water system, and a fuel element of slightly enriched uranium, clad with stainless steel, is more or less standard. A new fuel system for a reactor concept which holds bright promise (the organic cooled and moderated) has been devised together with techniques for its fabrication. It uses UO_2 as the fuel material capable of long exposure, is clad in sintered aluminum powder (SAP) or (APM) which has satisfactory strength and heat transfer properties.

Other studies on irradiation swelling have enabled us to provide metallic fuels for use at temperatures above the 1200° F. considered by many to be the minimum for economic power production.

Uranium carbide has been studied intensively as a fuel material. Laboratory methods of preparation and fabrication can be rapidly transferred to commercial practice when this material is needed. Its physical and metallurgical properties and its irradiation resistance make it a major contender as a fuel for high-temperature reactors.

Use of powder metallurgy techniques for alloys and cermets of aluminum as a fuel cladding and core structure material have been coupled with satisfactory techniques for closure and welding. Although its corrosion resistance is now adequate only for organic-cooled systems, trace amounts of other materials may enable it to be used with other coolants.

The use of zirconium as a fuel cladding and core material in power reactors has not progressed as rapidly as had been hoped. We are, however, still studying ways and means for reducing the cost of reactor-grade zirconium and improving its high-temperature mechanical properties and resistance to corrosion by steam.

[*]Excerpts from address by Frank K. Pittman, director of the division of reactor development, U. S. Atomic Energy Commission, before the Atomic Industrial Forum, Dec. 14, 1960.

Fuel fabricating techniques have been greatly developed and refined. The industry has standardized and improved its techniques for fabricating uranium oxide pellets. A fuel element made with oxide and having 90% of theoretical density is readily obtainable by vibratory compaction techniques. Successful use of this technique could eliminate the problems of individual pellet density, inspection of literally millions of pellets, the clearance between pellet core and cladding, "ratcheting," and size limitations – all factors which have a major impact on costs. This technique, while valuable for the virgin U^{235} now used for reactor fuels, would show its true worth when we are faced with the fabrication of recycled fuels by remote or semiremote methods. (This includes plutonium and U^{233}.) The method also lends itself to the fabrication of other ceramics, such as uranium carbide and thorium oxide. The major foreseeable problem is the expected increase in the amounts of fission gas which will be released from the fuel.

One of the most exciting developments in the fuel business, in my opinion, is the "coated particle" process for the manufacture of completely ceramic fuel bodies with no metallic cladding. Small grains of fissionable oxide or carbide – comparable in size to common table salt – are individually coated by a gas-decomposition technique using fluidized-bed procedures. The coating is a dense refractory material such as alumina or pyrolytic graphite which will serve the dual function of protecting the more reactive fuel material from reaction with reactor coolant at high temperatures and also of preventing the escape of the fission gas produced within the fuel. These individually coated fuel particles are then evenly dispersed in a matrix such as graphite, and the dispersion can be conveniently and economically shaped into fuel elements of various shapes and sizes by simple mass-production techniques.

Irradiation of a graphite matrix containing UO_2 particles coated with Al_2O_3 or with pyrolytic graphite at high temperatures for extended periods has released no fission products. The possibilities for such fuel elements are almost unlimited. They would be particularly attractive for high-temperature operations required for gas cooled and liquid-metal cooled reactor systems because less-refractory metallic cladding could be eliminated.

Brazing Missile and Electronic Components in Dry Hydrogen—II

*By H. E. LEWIS**

Purity of the atmosphere and control of temperature will determine the results obtained in brazing in dry hydrogen. Here are some pointers on minimizing contamination and regulating heating and cooling. (K8, T24e, T1)

As POINTED OUT LAST MONTH in the initial part of this article, many factors must be taken into account when brazing difficult metals. None is more important, however, than atmosphere purity. Even the type of hydrogen can be important. For example, hydrogen made from a hydrocarbon gas contains traces of hydrocarbons. This is undesirable when brazing materials subject to carbon contamination.

Electrolytic hydrogen, free of hydrocarbons, with an oxygen content of about 0.3 to 0.5%, is entirely satisfactory when purified and when the manufacturer's process and bottling control is good.

The usual method of purifying the hydrogen received by the brazer is to pass it first through a palladium catalyst to convert the residual oxygen to water vapor, then to pass it through an absorption-type dryer to remove the water vapor. If the deoxidizer and the dryer are well designed and of sufficient capacity, the hydrogen will be purified and dried to a very low dew point. Figure 1 shows some of the hydrogen purification equipment.

Welded Retorts – Maintaining purity of the atmosphere in a furnace is a constant problem, and no assumption can be made that, because the atmosphere introduced is very dry, it will be dry in the furnace retort. A positively sealed retort is necessary for maintaining very low dew points. Sand seals are simple but are not positive, and they have a number of disadvantages. Gasketed seals are not so simple, and also are not positive, particularly when the retorts are large. One way to insure atmosphere purity is to use a completely welded retort. The welding of the cover is simple, but its subsequent removal is a nuisance. These operations are not difficult or time consuming in the over-all process. The assurance of no leaks and no oxygen diffusing into the weld-sealed retort far outweighs the disadvantages.

Dew Point Control – Methods for checking the dew point of hydrogen vary from the use of a simple dew point cup costing a few dollars to the use of expensive recorder systems costing thousands of dollars. Because the moisture content of hydrogen in the range required for the type of brazing involved is in the order of one to ten parts per million, the need for accurate techniques and sensitive instruments is apparent. So much depends upon the accuracy of the device or instrument, its range and calibration, and upon the way it is operated and maintained that dew point readings can be doubtful. Some instruments are supposed to be accurate to -80° F. and some to -100° F. Because of the questionable accuracy of the readings in this range, it is advisable to insist that the dew point of the hydrogen entering a retort

*President and General Manager, Pyromet Co., San Carlos, Calif.

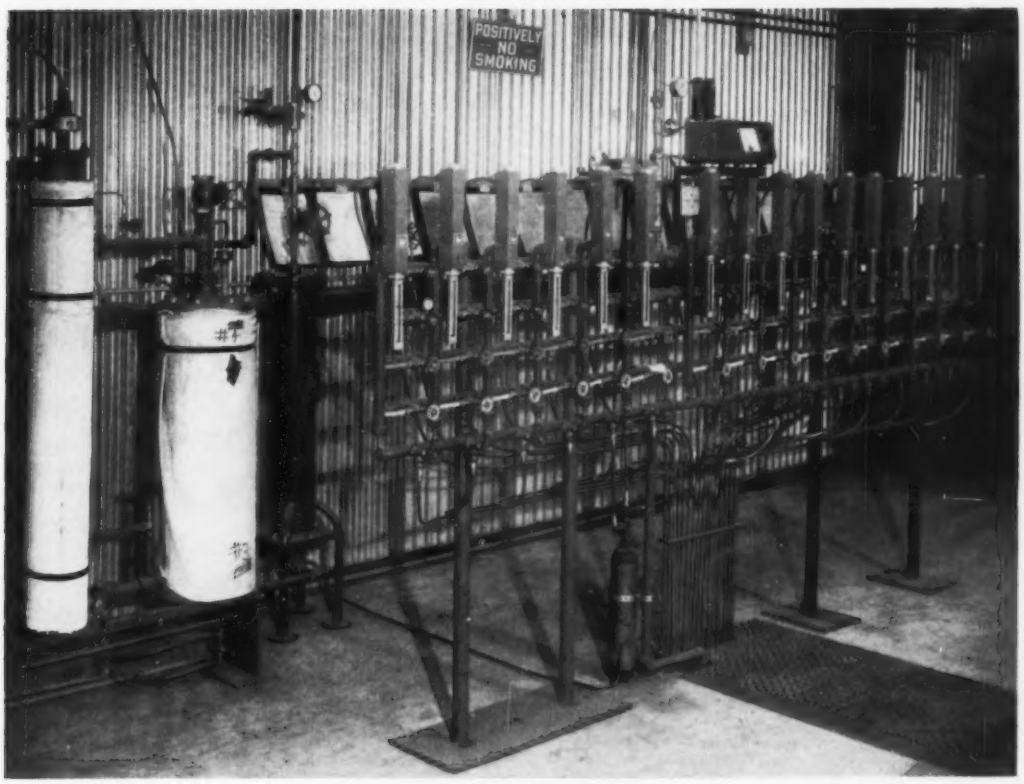

Fig. 1 – Purification Equipment and Flow-Control Manifold Serve a Battery of Furnaces With Dry Hydrogen of –80° F. Dew Point

be below the range of the testing instrument, or at least below that shown by the equilibrium data to be the minimum required in the retort.

Purging a furnace retort is a very important factor in successful brazing, particularly of stainless steel. The atmosphere should be introduced at the farthest part of the retort away from the outlet of the retort to provide a sweeping action. If possible, it should be preheated before it comes near any work to be brazed. If a cold inlet atmosphere impinges on the work, areas may not reach brazing temperature.

A sufficient volume of atmosphere should be used to provide five to ten changes per hour in the retort during purging and brazing. This volume may be reduced during the cooling cycle.

Cavities – Many assemblies contain cavities that will not purge readily. Sometimes they can be manifolded so that atmosphere can be introduced directly into them as well as around the outside of the assembly. A better way, if a welded retort is used, is to pull a rough vacuum on the retort. If the retort is not strong enough to stand much vacuum, a series of cycles may be used, first pulling a partial vacuum, then introducing dry hydrogen.

A dry-hydrogen atmosphere in a furnace retort is easily contaminated. A small leak will raise the dew point, even though there is a positive pressure in the retort and a good flow of hydrogen. Retorts should be checked for leaks before each heat.

Oxides reduced during brazing are a major source of contamination. These may be oxides that have not been removed from the parts themselves or they may be on fixtures or supports or the retort. For dry-hydrogen brazing, the only oxides allowable are those that will readily reduce at a low temperature.

Oxygen in metal can also cause contamination, as evidenced by trouble from electrolytic tough pitch copper and from copper sprayed on parts by metalizing. Both contain oxygen and should not be used.

Graphite and ceramic supports for assemblies can absorb oxygen and moisture which, on

heating, contaminate the retort atmosphere. This becomes a serious factor if these supports are large.

Regulate Heating and Cooling

The final major factor to be considered in engineering a brazing application is that of the heating and cooling cycle. What heating rate is required or is possible? And what will be its effect on the brazing alloy and on the components? Slow heating may result in liquation of the brazing alloy or in alloying the braze metal with the base metal. Fast heating may damage the assembly.

Because there is always a difference in temperature between the furnace outside the retort and the parts inside it, both temperatures must be considered. In specifying a brazing temperature, the temperature required at the parts is the one to use.

An allowable temperature range should always be chosen for the parts based on the component materials and the brazing alloy. A range of $\pm 5^{\circ}$ F. from the optimum temperature selected is reasonable.

Temperature Control – The entire temperature control and checking system should be of the highest quality and should be maintained by regular servicing and frequent calibration. Each furnace should be equipped with a potentiometer recorder-controller or with more than one instrument for multizone control if the furnace is large. The control thermocouple should be of a type that will not change calibration in the protective atmosphere or gases in the heating chamber. It should be remembered that a protection tube over the thermocouple will not always stop contamination. A "poisoned" thermocouple, reading 50° low may cause an overheated assembly. The control couple should be located to give a true reading of the furnace temperature, and the connections between the couple and the control instrument should be made with all precautions to assure no error of transmittal.

Check Parts – Two or more check thermocouples are desirable on the parts. Just how to attach these to the assembly in the vicinity of the joints to be brazed to give a true reading is sometimes a problem. However, temperatures should be known for accurate work, and means for attaching the couples must be found. The accuracy of the couples is a constant consideration; they should be replaced after a few heats. *(Continued on p. 118)*

For Good Brazing Results, Consider:

Materials of the components
- Composition
- Microstructure
- Surface condition

Brazing alloys
- Strength and operating requirements
- Melt, flow, and brazing temperatures
- Alloying characteristics with base metals
- Wetting characteristics
- Available forms

Joint considerations
- Design
- Clearance

Expansion considerations
- Dissimilar metals
- Differential heating and cooling

Heating method
- Furnace
- Induction

Dew Point
- Metal-metal oxide equilibriums
- Requirements for brazing

Joint preparation
- Cleaning
- Pickling
- Prefiring in dry hydrogen
- Plating

Alloy placement
- Form of alloy to use
- Location
- Method of application
- Quantity
- Masking

Furnace loading
- Retort size
- Supports and fixtures

Atmosphere purity
- Type of hydrogen
- Purification
- Maintaining purity in furance
- Checking purity
- Purging
- Sources of contamination

Heating and cooling cycle
- Heating rate
- Furnace temperature vs. work temperature
- Temperature range required for parts
- Controlling and checking temperature
- Time at temperature
- Cooling rate

How to choose a metal for high-temperature service

In every sense, "the heat's on" and "the pressure's on" when metals go to work at high temperatures. The basic trend in processing equipment has been toward higher pressures, higher temperatures, and more corrosive conditions.

That's why questions like these are being asked today: What metal is used within the core of a gas-cooled reactor where operating temperatures go up to 1700°F? What metal is used for the "skin" of a missile that must take supersonic heats from 400° to 600°F . . . and be the structural framework for 130 tons of dead weight? What metal is used to withstand the corrosion of hot ammonia gas at 900°F? What metal is used for strength and corrosion resistance above 1000°F?

The answer, in each case: Nickel Stainless Steel.

Nickel works as a strengthening and toughening agent. In steel it promotes the formation of austenite, which is stronger and more stable at high temperatures than ferrite. Nickel steps up steel's resistance to oxidation, carburizing, nitriding and thermal fatigue.

The war against corrosion. High-temperature equipment is exposed to a great many different atmospheres and corrosive conditions. Many materials coming from high-temperature processing and handling must be delivered uncontaminated by the products of corrosion. Nickel stainless steels are especially good for fighting corrosion . . . perform well under those oxidizing conditions harmful to unalloyed steel. The stainless steels possess the ability to protect themselves with oxide films that form a shield against corrosion. And *stainless* steel, as the name implies, stays brighter, cleaner . . . and the protective "oxide layer" is less likely to be broken or reduced by pitting or scaling.

What strength means at high temperature. By a mechanism known as "creep" metals at elevated temperatures flow plastically though subjected to stresses below their yield strength, as determined by short-time tensile tests. The creep strength of nickel stainless steels is an important reason for their increasing use in a variety of high-temperature operations. Both *time* and *stress* are design factors at high temperatures. The most generally useful data are those for creep and rupture—one or the other is the basis for most allowable stress values in design work.

The chart below gives the creep and rupture strength data of two nickel stainless steels that have found wide acceptance in high-temperature service:

	CREEP STRENGTH			
	1000°F		1500°F	
AISI TYPE	1% 100,000 hrs,psi	1% 10,000 hrs,psi	1% 100,000 hrs,psi	1% 10,000 hrs,psi
310	17,500	32,500	1,250	3,500
316	14,750	24,500	1,800	4,200
	RUPTURE STRENGTH			
	1000°F		1500°F	
AISI TYPE	100,000 hrs,psi	10,000 hrs,psi	100,000 hrs,psi	10,000 hrs,psi
310	21,000	25,000	1,600	2,800
316	—	—	1,600	3,400

Don't stop at creep and rupture strength . . . other critical questions must be considered in the selection of metals for high-temperature service. They include:

- high temperature ductility
- short-time tensile properties to help evaluate resistance to momentary overloads
- thermal shock resistance

Before selecting a metal for a specific service ask yourself these questions:

- ☐ What is the maximum temperature of operation?
- ☐ What kind of temperature cycling will occur?
- ☐ What maximum load will be encountered? Will it be constant or cyclic?
- ☐ What types of atmosphere or other corrosive conditions?
- ☐ What size or shape of the parts or sections?
- ☐ What further processing will be done, such as welding or machining?
- ☐ What abrasive or wear conditions will be encountered?

The nickel stainless steel family can serve you in a wide range of high-temperature operations. That's why it's best to bring your metal problem to Inco's High Temperature Engineering Section. They are fully prepared to give you practical answers on the metal that will work best in your application. A note to Inco will bring you the "High Temperature Worksheet" to guide you in describing your metal problem.

LITERATURE

The publications listed below will provide more detailed information on choosing metals for high-temperature service.

PUBLICATION NUMBER	NAME
A266	Heat Resistant Castings, Corrosion Resistant Castings . . . Their Engineering Properties and Applications
A227	Stainless Steel for Pressure Vessels
	High Temperature Corrosion in Refinery and Petrochemical Service
A164	Thermal Expansion Characteristics of Stainless Steels Between −300°F and 1000°F
A248	Compilations of Chemical Compositions and Rupture Strengths of Super-Strength Alloys

A complete listing of Inco publications and technical bulletins can be obtained by writing for "List A" to:

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INCO NICKEL

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Circle 1564 on Page 48-B

Machining 6 Al, 4 V Titanium (a)

Operation	Tool Material	Tool Geometry (*b*)	Tool Used for Tests	Depth of Cut	Width of Cut	Feed	Cutting Speed	Tool Life	Wear-Land (*c*)	Cutting Fluid
Turning Bhn. 312	C-2 carbide	SR: 6°; SCEA: 6°; BR: 0°; ECEA: 6°; Relief: 6°	⅝-in. square tool bit	0.050 in.	—	0.009 in./rev.	165 ft./min.	65 min.	0.015 in.	Soluble oil (10:1)
Turning Bhn. 365	C-2 carbide	SR: 6°; SCEA: 6°; BR: 0°; ECEA: 6°; Relief: 6°	⅝-in. square tool bit	0.050	—	0.009 in./rev.	150	70 min.	0.015	Soluble oil (10:1)
Turning Bhn. 312	M-3 HSS	SR: 5°; SCEA: 0°; BR: 0°; ECEA: 5°; Relief: 5°	⅝-in. square tool bit	0.050	—	0.005 in./rev.	65	65 min.	0.060	Soluble oil (10:1)
Turning Bhn. 365	M-3 HSS	SR: 5°; SCEA: 0°; BR: 0°; ECEA: 5°; Relief: 5°	⅝-in. square tool bit	0.050	—	0.005 in./rev.	55	70 min.	0.060	Soluble oil (10:1)
Face milling Bhn. 312 Down milling setup	C-2 carbide	AR: 0°; ECEA: 6°; RR: −10°; Cl: 12°; CA: 30°	4-in. diam., single-tooth face mill	0.050	2 in.	0.006 in./tooth	97	42 in./tooth	0.015	Soluble oil (20:1)
Face milling Bhn. 365 Down milling setup	C-2 carbide	AR: 0°; ECEA: 6°; RR: −10°; Cl: 12°; CA: 30°	4-in. diam., single-tooth face mill	0.050	2	0.006 in./tooth	97	62 in./tooth	0.015	Soluble oil (20:1)
Face milling Bhn. 312	T-15 HSS	AR: 0°; ECEA: 6°; RR: 0°; Cl: 12°; CA: 30°	4-in. diam., single-tooth face mill	0.050	2	0.005 in./tooth	78	50 in./tooth	0.060	Soluble oil (20:1)
Face milling Bhn. 365	T-15 HSS	AR: 0°; ECEA: 6°; RR: 0°; Cl: 12°; CA: 30°	4-in. diam., single-tooth face mill	0.050	2	0.005 in./tooth	78	45 in./tooth	0.060	Soluble oil (20:1)
Drilling Bhn. 312	M-10 HSS	2-flute, 118° standard point, 7° clearance	13/64-in. diam. drill, 2¾ in long (*d*)	0.250 through hole	—	0.005 in./rev.	32	175 holes	0.015	Highly sulphurized oil
Drilling Bhn. 365	M-10 HSS	2-flute, 118° standard point, 7° clearance	13/64 in. diam. drill, 2¾ in. long (*d*)	0.25 through hole	—	0.005 in./rev.	25	59 holes	0.015	Highly sulphurized oil
Tapping Bhn. 312	M-10 HSS	3-flute taper, spiral point tap, 70% thread	¼-20 NC spiral point tap	0.250 through hole	—	—	14	150 holes	Tap breakage	Highly sulphurized oil
Tapping Bhn. 365	M-10 HSS	3-flute taper, spiral point tap, 70% thread	¼-20 NC spiral point tap	0.250 through hole	—	—	14	30 holes	Tap breakage	Highly sulphurized oil

(*a*) For two heat treated conditions: Annealed to Bhn. 312; and solution treated and aged to Bhn. 365.
(*b*) AR = axial rake; RR = radial rake; CA = corner angle; SR = side rake; BR = back rake; SCEA = side-cutting edge angle; ECEA = end-cutting edge angle; Cl = clearance.
(*c*) Wear on the peripheral flank of the cutter. (*d*) Use stub length drills whenever possible.

Source: Metcut Research Associates

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Circle 1565 on Page 48-B

Fights Flux Attack to Cut Brazing Costs

Because of the severe destructive effects of flux used in aluminum and copper brazing processes, proper alloy selection and quality construction are the only answers to long belt life in this type of operation. Cambridge Cambriloy 35-19 Metal-Mesh Belts have successfully withstood flux attack in many copper brazing installations for as long as 6000 hours, giving users continued production of quality parts while cutting operating and maintenance costs.

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A New Cast Alloy for Use at 1900° F.

*By C. G. BIEBER and T. E. KIHLGREN**

Laboratory tests indicate that IN-100 – a new nickel-based alloy – has adequate tensile and rupture strength for turbine blades operating up to 1900° F. Data have been obtained from more than 30 heats. (Q-general, T7h, 17-57; Ni-b, 5-62)

IN RECENT YEARS, THE DESIGN of turbine blades has been somewhat hampered by limitations of materials. One approach toward solving this problem was to consider cast alloys which could be age hardened. They would be inherently stronger in creep rupture than the corresponding wrought composition and, more importantly, larger quantities of the elements providing high-temperature strength could be employed.

In 1956, the introduction of 713 C ushered in a series of cast alloys for turbine blades, the latest of which is IN-100. Usable up to 1900° F., this new nickel-base alloy contains 8 to 11% Cr, 13 to 17 Co, 2 to 4 Mo, 0.70 to 1.20 V, 5 to 6 Al, 4.5 to 5.5 Ti, 0.15 to 0.20 C, 0.008 to 0.02 B, and 0.03 to 0.09 Zr†. Also, iron is limited to a maximum of 1%, and aluminum plus titanium should be between 10 and 11.5%. The alloy is melted and investment cast in vacuum, and is presently used in the as-cast condition.

Some of Its Properties

This alloy has a tensile strength of 140,000 psi. and a yield strength of 122,000 psi.; strengths remain at those values to 1400° F. at

*Metallurgists, Research Laboratory (Bayonne, N.J.) and Development Research Div. (New York), respectively, International Nickel Co., Inc.

†Nominal composition of the alloy is 10% Cr, 15 Co, 3 Mo, 1 V, 5.5 Al, 5 Ti, 0.18 C, 0.015 B and 0.05 Zr. Iron is low and aluminum plus titanium is 10.5%.

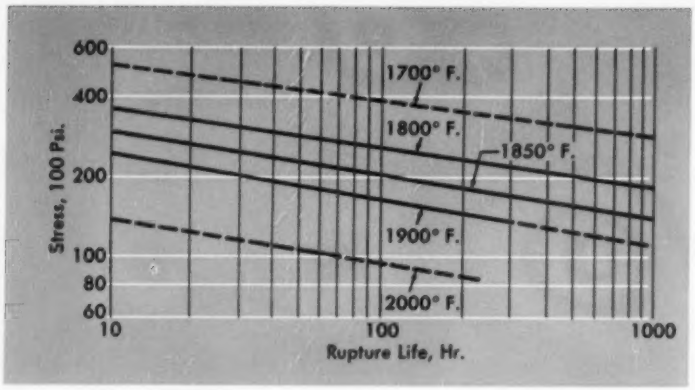


Fig. 1 – Stress-to-Rupture Curves for As-Cast IN-100. Tests from more than 20 experimental heats provided these data. Where only limited data were obtained, dotted lines are used

which point they begin to drop. Elongation varies between 6 and 8% up to 2000° F. Figure 1 shows stress versus time-to-rupture curves based on results taken from more than 20 experimental heats made by several producers and evaluated at six different laboratories.

For experimental production, specifications call for a minimum rupture life of 23 hr. at 1800° F. and 29,000 psi. stress with 4% minimum elongation. These figures are easily met by the new alloy. In fact, values of between 29 and 43 hr. with 7 to 9% elongation have been reported from the field on over ten heats made in production.

So that these properties may be more readily appraised, Fig. 2 illustrates the 100-hr. rupture strengths of a number of the cast turbine blade alloys which are available. The bar chart, Fig. 3, which lists properties of a number of wrought, age hardenable alloys along with those for the cast alloys, is included so that the relationship of the cast to wrought materials may be visualized. (Data on all proprietary materials are based on information available in current publications.) As for thermal shock resistance, IN-100 and 713 C are comparable.

To obtain high strength coupled with reasonable ductility at very high temperatures, it is often necessary to make some compromise with respect to other properties. Thus, in our new alloy, chromium content was lowered to accommodate the required amounts of aluminum and titanium. Because of this reduction in the chromium content (and because of the presence of vanadium, as well), the oxidation resistance is lowered somewhat. The data we have available at present indicate that the new alloy has adequate oxidation resistance for jet engines that operate at 1850 to 1900° F. For longer periods of operation or for higher temperature

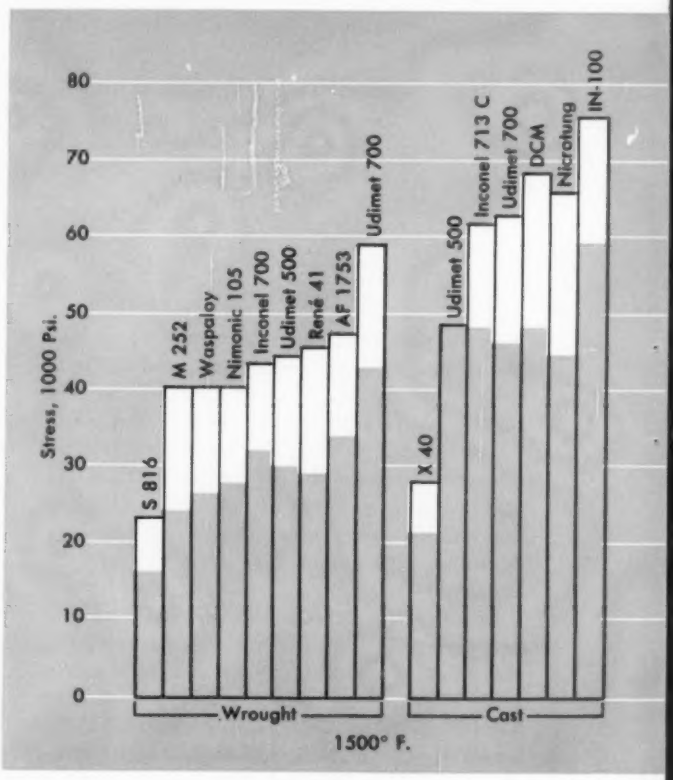
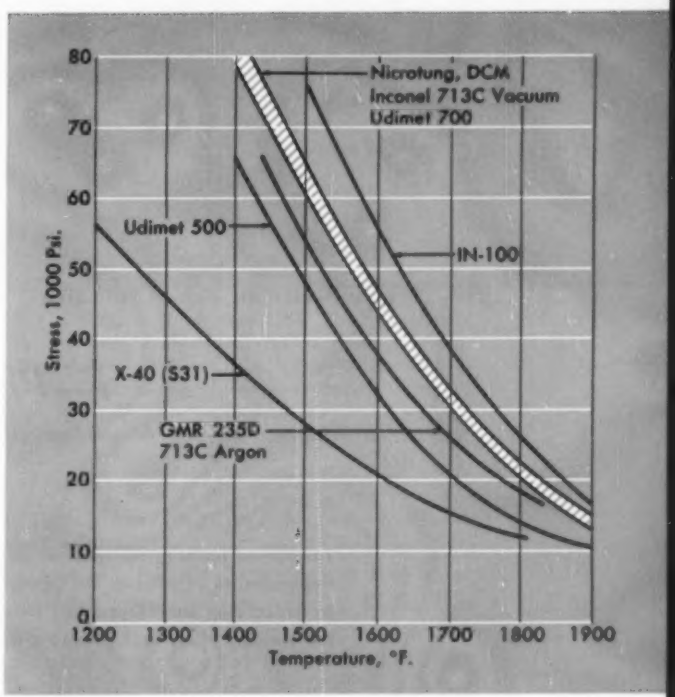


Fig. 3 – Approximate Rupture Strengths of Representative Turbine Blade Alloys, Both Cast and Wrought

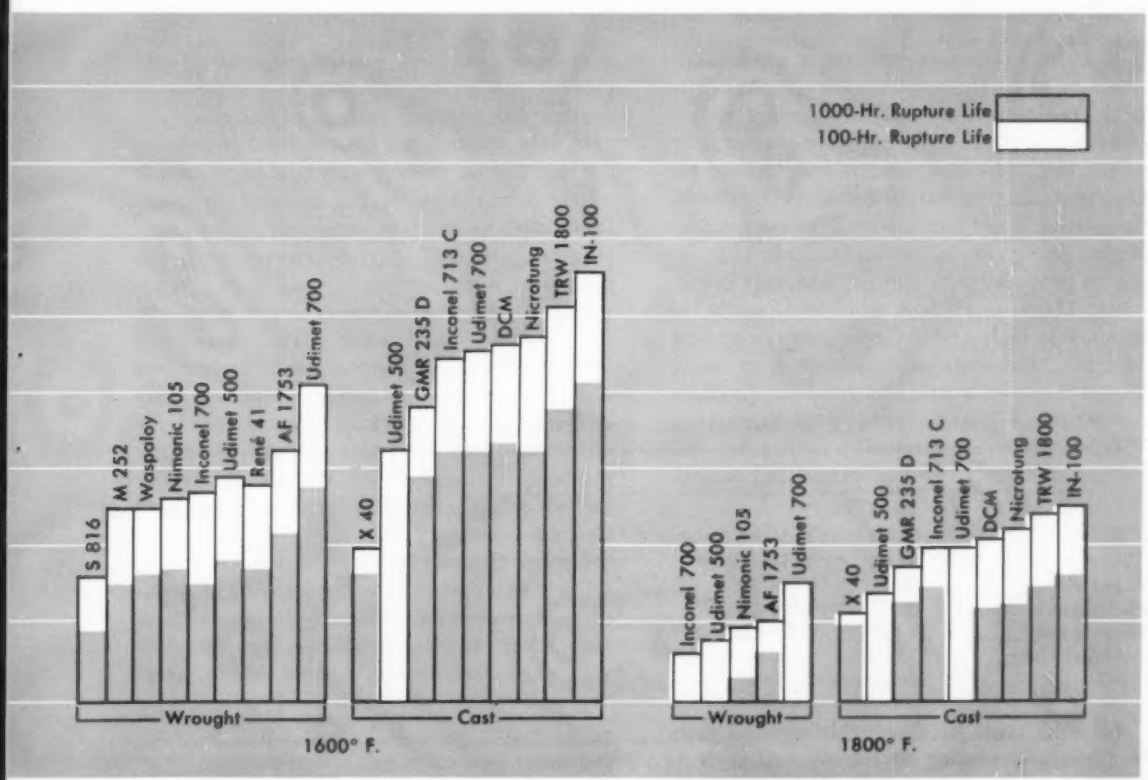
Fig. 2 – Comparison of the 100-Hr. Rupture Strengths of Several Cast Alloys Used for Turbine Blades



service, some type of protection such as aluminizing or chromizing may be needed for blades cast of IN-100. Though it may be observed that reducing the chromium content will also decrease the resistance to sulphide attack, the high titanium content and the presence of 1% vanadium appear to offset this.

A number of commercial shapes have been successfully produced by the investment casting method in the new alloy. However, where castings are subjected to extreme restraint in solidifying, some tendency to hot tearing has been observed. For such castings, boron and zirconium should be kept on the low side of the specification. In other instances, the nominal composition is preferred.

Sufficient experience has now been gained to indicate that the properties we list are readily realized on production heats. As experience accumulates, more complete information can be provided to those interested in the alloy.



No. 7 in a Series on Better Finishing

I—Phosphating in Cold Solutions

*By ROBERT C. GIBSON**

Improved techniques such as cold phosphating have resulted in expanded applications for phosphate coatings in protecting metal surfaces from corrosion and in preparing them for paints, vinyl and plastisol finishes.

COLD PHOSPHATE SYSTEMS, a recent innovation in which the solutions are operated 60 to 75° F. cooler than normal is becoming widely accepted as a method for applying coating prior to painting. Because there is less demand for heat, operating costs are reduced, yet quality of the coating is not sacrificed. Effective coatings of zinc phosphate and iron phosphate (Fig. 1) can be produced with up to 70% savings in heat costs. This is equivalent to 10 to 12 cents per automobile body or 4 to 5 cents per refrigerator cabinet. Conventional equipment is used. Figure 2 shows a unit designed for handling components for appliances.

The system is designed for cleaning and coating steel by spray application and has the following sequence of operations:

STAGE	TIME	TEMPERATURE
Cleaner	60 sec.	80 to 100° F.
Water rinse	60	80 to 90
Phosphate treatment	60	105 to 120
Water rinse	20 to 60	Unheated
Acidified rinse	15 to 45	Unheated to 160
Drying	Adequate to remove surface moisture	

All steel must be thoroughly cleaned prior to phosphate coating to remove soil such as grease, oil, rust and foreign material. These prevent or alter the formation of a satisfactory coating and interfere with paint adhesion.

In cold systems the cleaner used to remove oily soil before coating with zinc phosphate is a light-duty, mildly alkaline material especially formulated to function effectively at low temperature. If steel is to be coated with iron phosphate, it may also be cleaned, as an alternative to the alkaline solution, with a light-duty, low-foaming, mildly acidic mixture depending upon the conditions of operation. The required concentration of the cold cleaners will vary with the type of soil to be removed and the characteristics of the spray machine. Cleaners gradually accumulate soil and are finally discarded when contamination interferes with cleaning.

Excess cleaning solution and accumulated soil are removed by a water spray. The water rinse is overflowed sufficiently to prevent contamination. In some installations for producing zinc phosphate layers, a conditioning agent

*Professor of Chemistry, Adrian College, Adrian, Mich.; Technical Consultant, Parker Rust-Proof Co., Detroit.

added to the water rinse aids in forming a fine crystal structure.

After parts have been coated, they are rinsed in cold water to remove excess chemicals. Flow of water through the rinse is regulated with the rate of production so that contamination is minimized. The cold water rinse is then followed by an acidified rinse containing hexavalent chromium which enhances the corrosion resistance of the coating. Drying in an oven to remove surface moisture completes the process.

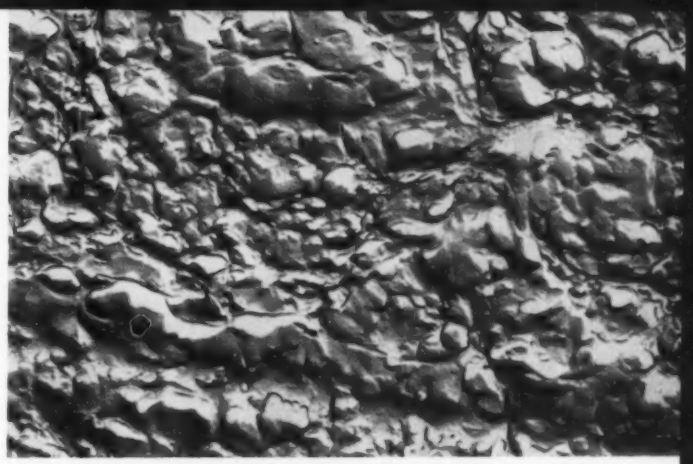


Fig. 1 — Micrograph at 18,000 × Shows Nature of Iron Phosphate Applied During Cold Phosphating. Smooth, fine-grained structure of the light coating (150 mg. per sq.ft.) results in a more uniform paint film and better paint texture than do coatings applied in hot baths

Advantages of Cold System

Examples of the types of products being treated by the cold phosphate system are automotive body and sheet metal parts, refrigerator cabinets, office furniture, lighting fixtures, air conditioners, home heating equipment, home laundries, kitchen cabinets and desk and filing cabinets, steel drums and window sash.

Compared to conventional methods, the cold phosphate system offers these advantages:

- Direct savings in heating costs of up to 70% are possible.
- Less heat up time is required.
- There is less maintenance due to decreased load on heating equipment.
- Down time is reduced. Maintenance personnel can enter the units immediately after shut-down to make adjustments or repairs.
- Working conditions are better near the installation.
- Water consumption is reduced because evaporation is cut down.
- Exhaust fans are no longer needed.

Data in Table I show how the change to a cold phosphating system cut the heating requirements in an automobile body plant. In this instance savings of 7,200,000 Btu. per hr. or 7200 lb. of steam per hr. were realized. Using $0.45 for the cost of coal to generate 1000 lb. of steam, the hourly savings in fuel alone (overhead, labor, water excluded) is $3.25. This amounts to about $600 per month in savings for a single body processing unit for one shift. Coating quality and the costs of chemicals are the same with both the hot and cold systems.

Other examples: A manufacturer of metal cabinets reduced gas consumption for heating his phosphating line by 56%; a maker of household equipment and manufacturer of a small appliance showed reductions in heating costs of 66 and 45%, respectively.

Modern Industrial Applications

Recently there has been a great deal of interest in heavy vinyl plastisol coatings as a replacement for porcelain enamel. Several major manufacturers of domestic dish washers, for example, have standardized on plastisol

Table I — Comparison of Heat Requirements for Hot and Cold Phosphating Systems*

Operation	Hot System		Cold System	
	Operating Temperature	Heat Required	Operating Temperature	Heat Required
Cleaner	168° F.	4,000,000 Btu. per hr.	85° F.	1,000,000 Btu. per hr.
Water rinse	155	1,575,000	85	225,000
Water rinse	150	1,350,000	85	225,000
Phosphate treatment	135	1,200,000	110	600,000
Water rinse	122	—	—	—
Acidified rinse	140	1,575,000	100	450,000
Total		9,700,000 Btu. per hr.		2,500,000 Btu. per hr.

*Installed in automobile body plant.

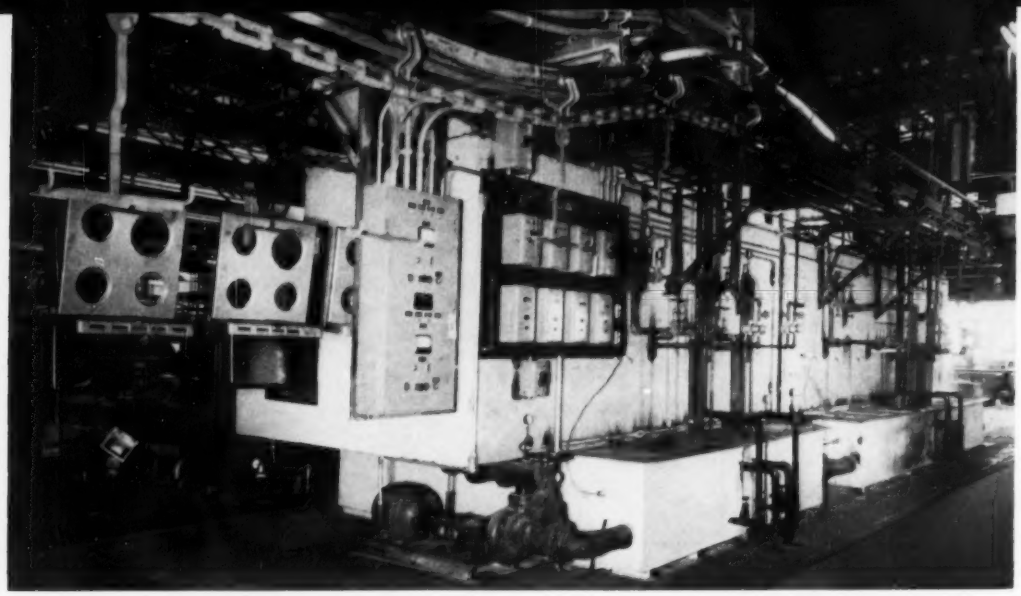


Fig. 2 – Treating Parts for Appliances Is a Good Application for Cold Phosphating. Spray process shown here includes cleaning, rinsing, phosphating, rinsing and drying

films for coating the tubs, lids and dish racks.

Early tests showed that the base metal would have to be treated in a manner which would promote adhesion of the plastisol coating and at the same time provide moisture (blister) resistance in the severe "vapor-life tests". A zinc phosphate coating fills these requirements. Fabricated parts are cleaned in a conditioned cleaner, phosphated and rinsed thoroughly. The procedure includes an acidified chromic-phosphoric acid rinse followed by a closely controlled rinse in de-ionized water and thorough drying. This treatment produces a continuous, uniform, fine-grained coating of about 150 to 250 mg. of zinc phosphate coating per sq.ft. of surface area.

Some manufacturers have incorporated additional stages in this continuous spray system to provide a phosphoric acid pickle which is maintained at a constant composition by an ion-exchange unit. The pickle removes steel mill contaminants from the surface of the steel and levels off the "pickle-lag variable" between different heats of steel or steels from different suppliers.

After the steel has been coated with zinc phosphate, it is covered with a thin film of specially formulated primer followed by 12 to 15 mils of plastisol with an intermediate and final baking operation.

Field tests have shown the complete practicability of this system and manufacturing method. It is predicted that plastisol coatings will find extended and wide use in the domestic appliance field during the next few years.

Bonds Organic Coating to Steel

Similarly, the application of vinyl to metal is a recent development in metal finishing. Vinyl film 5 to 15 mils thick is applied to steel and aluminum sheets by laminating or by spray or roller coating. As with plastisol applications, the base metal must be chemically treated to provide a good bond between the vinyl and metal surface. An accelerated iron phosphate treatment followed by an acidified chromate rinse has proved to be best in preparing steel for this purpose.

Aluminum can also be finished with vinyl laminates and plastisols. Chromate conversion coatings of the "gold" oxide type give good adhesion of the vinyl film as well as excellent corrosion resistance to the uncoated surface.

Metal preparation for both steel and aluminum is usually done by spray application in five-stage equipment in the following sequence:

Alkali cleaner – 30 sec. (Smutty steel may require brush scrubbing).

Water rinse – 10 sec.

Phosphate treatment – 10 sec.

Water rinse – 5 sec.

Acidified chromate rinse – 5 sec.

For aluminum, the same sequence and time cycles are used, but an appropriate chromate conversion coating solution is substituted in stage 3. Installations have been engineered to prepare both steel and aluminum for vinyl coatings by using interchangeable tanks at that stage, providing efficient and versatile "in-line" operation for this new decorative treatment.

II—Phosphating in a Nonaqueous Solution

STAFF REPORT

Nonaqueous phosphating solutions based on trichlorethylene combine fast action and low operating costs. They can be used in separate tanks to process parts in batches or in automatic machines which degrease, phosphate and finish parts with paints thinned with trichlorethylene.

THE ABILITY TO PHOSPHATE METAL PARTS in nonaqueous solutions marks one of the newest innovations in metal finishing. In this process, the result of work at DuPont's Chestnut Run Laboratories near Wilmington, Del., phosphating is done by compounds dissolved in trichlorethylene. As in solvent-vapor degreasing, the bath is heated to its boiling point (188° F. for trichlorethylene). Parts are phosphated by either spraying or dipping them in the solution. After they pass through the vapor zone above the bath, they emerge from the unit with a completely dry coating, ready for processing.

One of the most immediate applications for nonaqueous phosphating is that it lends itself to in-line installation between vapor degreasing and trichlorethylene-based painting units. This arrangement offers the advantage of a relatively compact cleaning, phosphating and painting system which requires less space and is less expensive than aqueous systems that will do the same job. DuPont engineers also point out that operating costs are lower.

Three-stage equipment which degreases,

Fig. 1 — Large Body Panels for Buses Are Vapor Degreased, Then Dipped in a Nonaqueous Phosphating Solution in Open Tanks at Marmon-Herrington Co., Inc., Indianapolis. Treating cycle: 1½ min. immersion in vapor degreaser followed by 1½ min. in boiling phosphating solution

phosphates and paints has already been installed in an automobile engine plant. Parts traveling on a conveyer are first passed through a vapor-spray-vapor degreaser, then dipped in the trichlorethylene-based phosphating solution, followed by a dip in a paint which uses nonflammable trichlorethylene as the sole thinner. This setup processes about 10,000 to 12,000 sq.ft. of metal surface per day. With the standard application of 0.6 to 0.7 mil of air-dryed asphaltic-alkyd paint over the iron phosphate coating, the parts hold up at least 120 hr. in the salt spray test. This is well over the specified minimum of 72 hr.

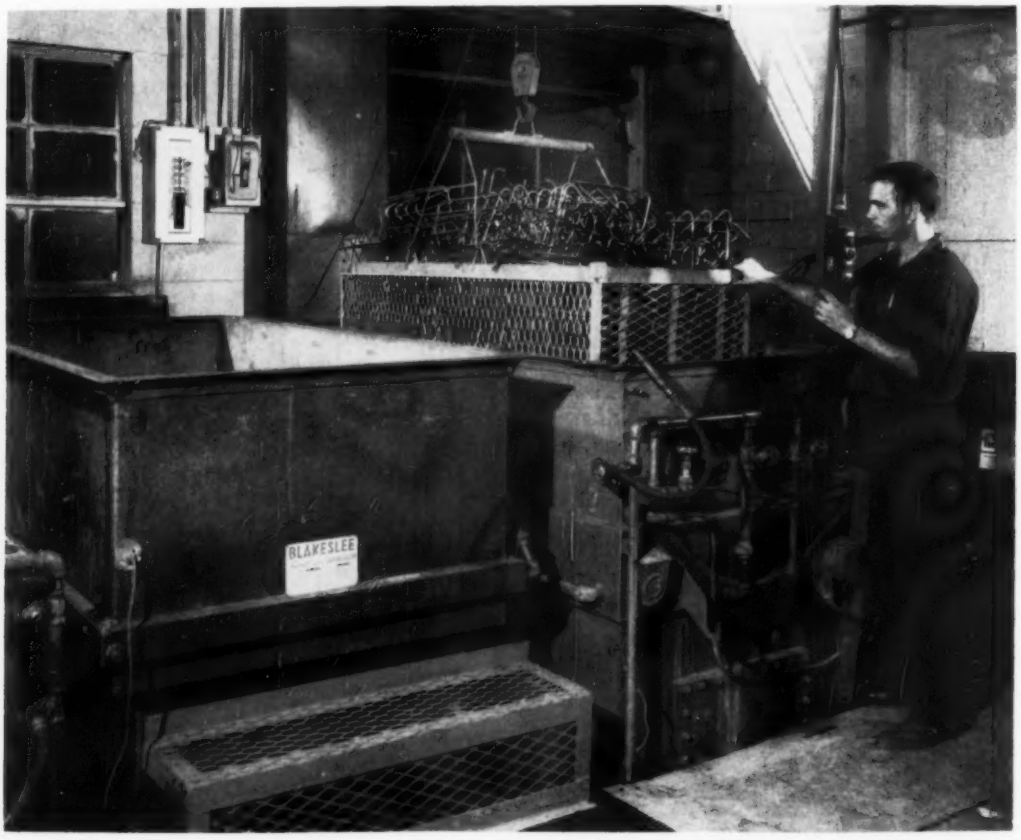
Large Panels Phosphated

Another plant uses the trichlorethylene-based phosphating system to coat panels for bus bodies. The finishes of samples which are subsequently painted with 1½ to 2 mils of an epoxy-based primer hold up for extended periods in salt spray. These large body panels are processed in batches at Marmon-Herrington Co., Inc., Indianapolis, in two tanks, one for vapor degreasing, the other for dip phosphating (Fig. 1). Production rate reaches about 30,000 sq.ft. per day.

Other batch operations are shown in Fig. 2 and 3. Equipment in Fig. 2, installed at the Ludington Plating Co., Ludington, Mich., has the advantage of being able to handle a large number of parts quickly and efficiently. Figure 3 shows an arrangement for degreasing and phosphating large panels in a limited space.

Since its introduction late in 1959, the new system has been installed in seven metalworking plants. Although these are operating units, either completely automatic as in the engine

Fig. 2 – Baskets Containing Large Numbers of Wire Racks Are Cleaned and Phosphated in Trichlorethylene-Based Phosphating Solution at Ludington Plating Co., Ludington, Mich. Ability to handle many parts quickly and efficiently was key point in selection of the process and equipment



plant or manually controlled, they are also being used to evaluate the process in the field before it is made fully available on a commercial scale.

Heavy Coatings Applied

The coating which is produced by the anhydrous phosphating solution is a true iron phosphate. A new formulation, made available last July, applies it at a rate of about 150 mg. per sq.ft. in less than 60 sec. and 200 mg. per sq.ft. in about 90 sec. Introduction of the new bath has delayed the availability of the process on a full commercial scale while studies in the field and in the laboratory are being made to evaluate such factors as the characteristics of the system, what can and cannot be expected of it, the performance of the bath, and the influence of paint quality. Data are being collected through a cooperative program between users and DuPont, an arrangement which DuPont insists on before making the process available.

Currently, systems combining vapor degreasing with anhydrous phosphating are less expensive than five-stage wet systems where the added alkaline cleaning units are needed to prevent contamination of the phosphating solution. Compared to three-stage wet phosphating, which is satisfactory if the soil on the parts can be handled by the wash-phosphating bath, the vapor degreasing-nonaqueous phosphating system is still competitive, but offers smaller savings. Continuing work on the nonaqueous process – formulation of faster-acting solutions, for example – is expected to improve this cost picture.

Fig. 3 – Closed-Circuit Arrangement Including Vapor Degreasing and Trichlorethylene-Based Phosphating Was Installed at This Plant Primarily to Conserve Floor Space

Trends in Aerospace Manufacturing

By W. D. NELSON,
J. A. SCOTT
*and R. H. GASSNER**

Although new forming and shaping methods, such as chemical milling, electromachining and grinding, subzero and thermal machining (among many others), are used primarily in the aerospace field at present, they could spark a revolution in the manufacture of conventional items. This report covers progress already made and outlines many of the fabrication problems which remain to be solved in the fabrication of missiles, rockets and aircraft. (G24, G-18, L-general, K-general, T24, T2p)

SINCE WORLD WAR II, DESIGNS for aircraft and spacecraft have called for stronger structures with maximum stiffness, minimum weight and good heat resistance. Initially, weight-saving objectives brought about a change from sheet metal designs to thick skins which were often integrally reinforced. Then, supersonic flight introduced the need for thinner airfoils, stiffer and more compact fuselages, and materials with stable properties under aerodynamic heating conditions. Currently, missile and spacecraft booster and sustainer designs have required absolute minimum weight, albeit for a single flight. During the last 15 years, these needs have mothered many revolutionary and evolutionary developments in manufacturing techniques. Their current status and future promise, as described at the 1960 S.A.E. National Aeronautic Meeting in Los Angeles, is the basis for this report.

Certainly, one of the most challenging problems facing aerospace manufacturing engineers today is that of reducing the costs of removing metal from the high-strength, tough, and exotic materials which must be used in tomorrow's vehicles. As one answer, many new "high-production" methods are now about ready to be adapted for machining "impractical" shapes from materials hitherto considered very difficult or impossible to machine.

Chemical Milling

One method which immediately comes to mind is chemical milling. The original application of this process was in fabricating duct skins of aluminum alloy for the F-100. Since then, as techniques have evolved for milling magnesium, titanium and stainless steel, design simplifications have been realized in a large variety of aircraft and missiles. In the F 8 U, for example, magnesium skin assemblies (which had been built up by bonding as many as seven detail parts) were produced as simple, one-piece units by chemical milling. Later, B-58 designers began to employ milled waffle patterns for stiffening – they had previously been impractical to fabricate in titanium alloy and stainless steel parts.

As for applications to come, the outstanding example is in the sizing and tapering of thin PH 15-7 Mo face sheets for honeycomb sandwich skins on the B-70. Engineers have devised several proprietary methods which appear capable of meeting specified thickness toler-

*Mr. Nelson is test engineer, Mr. Scott is metallurgist, and Mr. Gassner is chief metallurgist at Douglas Aircraft Co., El Segundo, Calif. Mr. Gassner is also a consulting editor for *Metal Progress*. This is a report of the S.A.E. Aerospace Manufacturing Forum held in Los Angeles, October 1960.

ance requirements of ±0.001 in. However, the etching mediums are more corrosive than aqua regia, and they must be maintained at elevated temperatures. To date, no equipment fabricators or material suppliers have been willing to build and guarantee a complete chemical milling installation which will operate under those conditions for extended periods. Nevertheless, the operation will have to be done. Certainly, economics is not the question – not when each unnecessary thousandth of an inch adds about 2000 lb. of extra weight to the B-70.

Another challenge which will be facing the chemical milling industry will be in converting laboratory methods for milling refractory metals and beryllium to production processes. With respect to beryllium, chemical milling will, when in use, eliminate the hazard which results from mechanical machining – no toxic beryllium dust will be produced.

Electrical Machining

Electron beam machining is one of the newest methods by which material can be removed by direct application of electrical energy. In this process, high-velocity electrons are focused into a sharp, thin beam. By using a 0.5 micron beam, it is now possible to drill holes 1 micron in diameter, and machine slots as narrow as 0.0008 in. During such an operation, the energy density may go as high as 600 million watts per sq.in. To attest to the success of this method, it has been applied to drilling small holes in such items as sapphire bearings. One automatic installation, in fact, currently produces 600 drilled jewel bearings every hour.

Electrodischarge machining, having reached a much higher state of development than the electron beam method, is already a standard technique in many industries. Though the actual mechanism of material removal is still not completely understood, many investigators believe that the high specific energy of the spark melts small projections on the workpiece surface; the molten particles are then attracted to the cathode as drops or tears. Individual sparks may have current densities as high as a million amp. per sq.in. at frequencies from 10 to 1000 kc.

Efficiency of the process is little affected by the mechanical or physical properties of the workpiece so long as the material conducts electricity reasonably well. However, the surfaces of some materials can be damaged and cracked by excessive heat, and steels are often slightly decarburized. Also, residual stresses at the surface may be several times those resulting from conventional grinding; this can affect fatigue life adversely.

Advanced Technologies in the Fabrication of Space-Age Metals Have Enabled Aerojet-General to Erect Larger Motor Cases for the Polaris. Shown on the right is the motor for the Polaris A-2. Thirty inches longer than the A-1 motor on the left, it increases the effective range of the missile to 1500 nautical miles

In spite of these disadvantages, applications of electrodischarge machining range from cavity sinking in carbide die blocks to contouring honeycomb. (It is particularly well suited for the latter operation because the tool doesn't contact the foil.) Tolerances on the order of 0.0001 in. are obtainable and finishing cuts may be as smooth as rms. 10.

Electrolytic grinding has been successfully used for cut-off operations, surface grinding, machining of honeycomb, and burr-free grinding of small parts. When applied to the shaping of carbide tools, carbides can be re-

moved much faster and diamond wheel consumption is greatly reduced. Material is removed essentially by electrolytic dissolution or deplating; the abrasive in the wheel merely prevents a direct electrical short and sweeps away any polarizing film. As with electrodischarge machining, the work must conduct electricity. Efficiency of the process depends on the chemical valence of the dissolved work material.

Parts can be ground without inducing heat effects or surface stresses to produce a surface finish approaching rms. 2 with tolerances similar to those obtainable by conventional grinding. Furthermore, most conventional grinders can be adapted for the process by merely isolating the spindle electrically, installing brushes on it, and supplying means for handling the electrolyte (a potassium nitrate solution).

Thermal Machining

A 50 to 300% increase in tool life or cutting speed (or both) is possible by use of subzero coolants in some standard machining operations. The greatest potential increase in cutting speed occurs with single-point turning; however, tapping operations are not greatly improved. Also, milling operations employing carbides are generally adversely affected by the use of subzero coolants. Thus, although subzero coolants are useful in specific instances, they are not a cure-all. Factors which must be considered carefully are *(a)* a CO_2 mist costs about nine cents per min., *(b)* maximum cutting speeds cannot always be used on parts either too small in diameter or too short, and *(c)* tool dwell must be avoided when turning short lengths.

Machining at temperatures up to 1200° F. can improve tool life to about 100 times that experienced in room-temperature machining. As with subzero cooling, the degree of improvement also depends upon the specific application. For example, face milling tests on induction heated AM 350 (Bhn. 380) have shown tool life at 1000° F. to be about 100 times normal. On the other hand, turning tests on AM 350 (Bhn. 400) and 4340 (Bhn. 600) at various temperatures up to 900° F. have revealed increased tool lives of only 5 times and 20 times, respectively. Further, there is no advantage to be gained by heating 4340 when drilling with either high speed steel or carbide drills. Hot machining is currently limited to roughing operations where high metal removal rates are most valuable. This limitation is imposed by the problem of distortion of the workpiece, not the inability to produce smooth surfaces.

Ultra-High-Speed Machining

New concepts of machining and machine tool design are being obtained by shooting specimens of A.I.S.I. 4340 from a 20 mm. cannon past cutting tools at up to 240,000 sfm. For both annealed and heat treated 4340 steel (to 280,000 psi.), the most efficient speed is 120,000 sfm. At this speed, tool wear is at a minimum, and the cutting force required is only about half that required at 90,000 sfm. Cutting temperature does not rise, and surface finish does not appear to be affected by cutting velocity. Results of tests of this nature indicate that further pursuit of basic data and experience in ultra-high-speed machining may lead eventually to a new generation of machine tools for the space age.

Cleaning, Coating and Plating

If the challenge of the next decade is to be met, a rapid rate of progress will be required in cleaning technology to keep pace with the widening stream of new materials and processes emerging from our laboratories. In many of the more complex aerospace components, the major problem will be to determine the minimum degree of cleanliness which is necessary, and then devise methods which will effectively insure that the standard is consistently met. One suitable way to accomplish this purpose is to add small quantities of radioactive iodine, an isotope with a short half-life, to the soil. Then, the difference in radioactivity before and after cleaning indicates the effectiveness of the cleaner in a quantitative manner. In this way, process engineers may be able to evaluate various cleaning systems.

Cleaning is aided by agitating conventional cleaning solutions ultrasonically. By this means, many otherwise impossible-to-clean parts may be cleaned, and many difficult-to-clean parts can be cleaned more efficiently. Further, it will be possible to employ more potent cleaners because lower concentrations and cleaning times will be effective. Consequently, personnel toxicity hazards, deterioration of tanks and tank coatings, and corrosion or etching of parts will be minimized or eliminated. In addition, ultrasonics may prove to be an invaluable aid for cleaning confined areas,

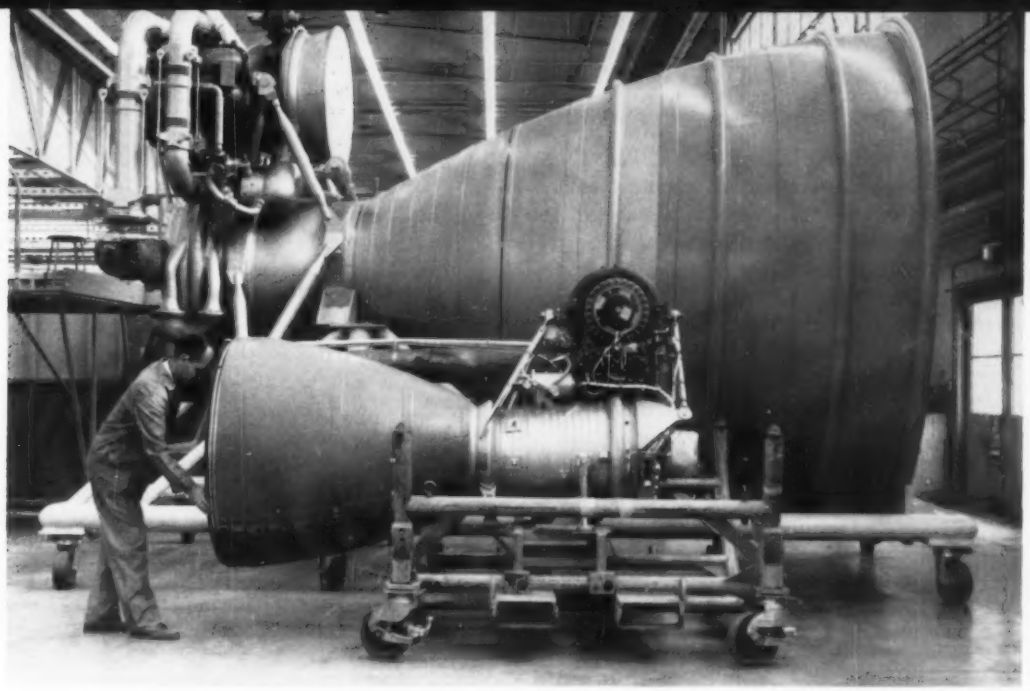


Fig. 1 – Illustrated Here Is a Mock-Up of the F-1 Rocket Engine Being Developed at North American Aviation. Generating up to 1,500,000 lb. of thrust, this motor will be powered by RP-1, a liquid oxygen-kerosene type fuel

such as deep recesses and crevices, and for cleaning assemblies without resorting to time-consuming disassembly, rubbing, soaking, and reassembly.

Needed – Better Coatings

In the future, we must devise oxidation resistant coatings for protecting structural materials at high temperatures. Without such coatings, those materials having useful strength at the temperatures to be encountered in tomorrow's aerospace vehicles will oxidize catastrophically before reaching their service temperatures. This unfortunate characteristic is exemplified by severe oxidation of graphite slightly above room temperature, oxidation (and volatilization of the oxide) of molybdenum at 1200 to 1300° F., and self-sustained combustion of columbium in air at about 2500° F. As one answer, oxidation resistant graphite parts are now being produced. As reported in *Metal Progress* (Technical News, August 1960, p. 68), they are pressed, cured and sintered from a composite of graphite, ceramics (molybdenum disilicide and titanium boride) and a binder of furfuryl alcohol. In service (3000° F. maximum), the surface graphite oxidizes, and the exposed ceramic particles fuse to form an oxidation resistant layer which is self-healing.

Development of coatings for controlling the temperatures of space vehicles is another immediate necessity. Since the spacecraft designer has left "conduction" and "convection" behind on earth, he has only "radiation" left to heat or cool his craft. Assuming that the ship neither gains nor loses material, its temperature will be governed by the absorptivity and emissivity of its skin. As an example, a vehicle covered with aluminum would be hotter than a white-painted vehicle even though aluminum is the better reflector because white paint more readily emits the heat it absorbs. If heat radiation is desired, a high emissivity surface, approaching that of a black body, is required. However, when heat must be retained, a low emissivity surface, such as mirror-finished gold, silver, or aluminum, is needed.

Electroplating Should Be Improved

Gold plate seems to be the most practical coat; silver tarnishes readily and a uniform coating of aluminum is very difficult to deposit. However, gold-plating solutions currently in use do not appear capable of depositing coatings which are thick enough. Thin coatings tend to alloy with the base metal, thereby reducing corrosion resistance and raising emissivity.

Two approaches to the solution of this problem appear possible. Either new gold-plating techniques or techniques for applying an intermediate coat such as nickel will have to be developed. With respect to the former, a bath containing Turkey Red Oil has been reported

capable of plating gold up to 0.030 in. thick.

A third kind of coating which must be improved is that used for protecting metal surfaces during heat treatment. Conventional protective atmospheres have proved unsuccessful for achieving and maintaining a desired chemical composition and finish at the surfaces of many of the newer alloys. Furthermore, the inert gases, helium and argon, with maximum contaminant levels of 8 ppm., are extremely costly. This has dictated use of protective coatings.

However, those protective coatings available are far from optimum for large-scale production operations. Uniform electroplates are somewhat costly and limited to temperatures at which they do not diffuse into the base metal. Metallic paints are relatively easy to apply, but they must be handled carefully after application. Further, their organic binders present a hazard of carbon pickup. The ceramic paints require either a reaction with an oxidizing atmosphere (reactive type) or a temperature high enough to melt the ceramic (fused type).

Welding and Brazing

The advent of a whole new family of space-age materials, coupled with extremely thin gages and close tolerances, has had a tremendous effect on welding and brazing techniques and their applications. In weld joint design, the trend has been toward self-aligning joints; these help to ease assembly, tooling and fabrication problems. Instruments such as joint sensing devices have also been used more and more, particularly because of extremely thin gages and the increased necessity for welding tapered and stepped surfaces. Use of induced magnetic fields promises to eliminate arc wandering, a troublesome characteristic resulting from local magnetic or surface oxidation variations in such alloys as cold worked austenitic stainless steels.

Further examples of trends in welding are reduction of shielding gas flow through torch cups, electrostatic cleaning of filler wire, and acceptance of the new short-arc, or dip transfer, process. For back-up materials, aluminum oxide and titanium bars are now being applied; their low thermal conductivities offer the welding engineer an opportunity to concentrate heat in the weld area, thus reducing total heat input. Argon is also being cooled to subzero temperatures for more efficient use as a back-up gas. This technique helps to improve grain refinement and reduce preferred orientation in the weld beads. Among other new methods are ultrasonic welding, electron beam welding, explosive welding, foil seam welding, exploding foil welding, and use of auxiliary vibration during arc welding.

Many recent advances in welding techniques have resulted from the tremendous efforts of the missile industry. Rocket motor cases of steel now contain welds having 100% joint efficiency at 260,000 to 280,000 psi. Aluminum tanks for liquid-propellant rockets are being fabricated from high-strength alloys hitherto considered unweldable. Though crack-free welds are now routine, designers can only achieve 100% efficiency by thickening the joint adjacent to the bead. The steel cases are subject to all the troubles accompanying heat treatment of a complex welded assembly, and the aluminum tanks require a metal removal operation (usually chemical milling) to reduce the material thickness in areas not requiring beef-up or stiffening.

Brazing Techniques Are Advancing

Brazing techniques have also advanced so rapidly, particularly in the field of sandwich construction, that aircraft designers at North American Aviation now feel safe in specifying honeycomb sandwich of brazed stainless steel for skins on the B-70. In these assemblies of PH 15-7 Mo alloy, the foil in the honeycomb has to be within 0.001 in. of the specified thickness, and the face sheets must not vary from perfect flatness by more than 0.002 in. Also, the entire assembly must exhibit similar dimensional control while simultaneously allowing for 0.0043 in. per in. expansion during heat treatment. To assure that the critical cleanliness standards for detail parts are continuously met, plans include both radiographic and ultrasonic inspection of brazed sandwiches.

In short, this conference summed up the great progress which has already been made in the fabrication of space-age materials, and outlined areas in which further research must be done. The value obtained from each increment of added cost has never before received such emphasis. Cross-pollination of ideas among experts from many different fields will certainly bear fruit in the months ahead. Many of today's problems will be solved, but since many new ones will take their place, future conferences of this type will continue to play a major role in accelerating the progress of those on the road to solutions.

Short Runs

In Solder, Flux Makes the Difference

*By JOSEPH D. KELLER**

A simple test enabled engineers at Martin-Orlando to select one particular solder from a group, all of which had previously met government specifications for metallic content. Now being used at the Florida plant, this scientifically chosen solder has shortened some manufacturing jobs considerably. (K7; SGA-f)

IS ALL CORED SOLDER THE SAME? No matter who the manufacturer, it has to be certified, hasn't it? After all, cored solder must meet certain specifications, particularly if it is to be used in parts being made to fulfill government contracts. Then all cored solder must be just about identical, musn't it?

Contrary to logical expectation, the answer is "No!". While the metallic composition of the solder generally meets the rigid specifications, we found that the soldering action can vary considerably with the quality of flux in the core.

How the Work Was Done

When we began, we knew that all solder used at Martin-Orlando was certified and notarized and that it had the "stoichiometry" required to assure proper metallurgical alloying of solder to base metal. Yet, there were differences among the various brands. And if the tin and lead content of all of the makes of solder was essentially the same, the difference had to be in the flux – in the rosin core, in other words.

To determine the effect of flux on base metal, the test illustrated in Fig. 1 was undertaken. In this test, a known weight of cored solder is held perpendicular to the test specimen (which can be copper, iron or other metal). As the specimen is heated to 500° F. (on a hot plate),

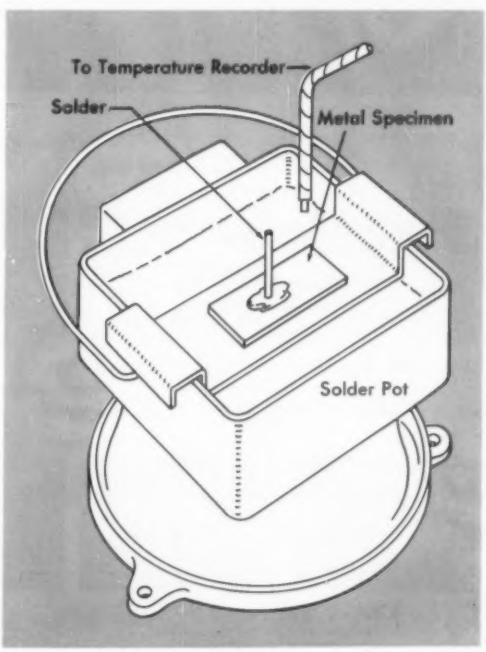


Fig. 1 – Test Setup for Rating Solders. A given weight of cored solder is melted by a steady 500° F. heat. "Solderability" is determined by the area covered by the resulting blob of melted solder

*Group Engineer, Metallurgical Research, Manufacturing Research and Development Section, Manufacturing Engineering Dept., Martin Co., Orlando, Fla.

the solder melts. When cool, the area of solder spread is calculated – we used a planimeter for this purpose.

Tests were repeated with several brands of cored solders, the copper specimen being replaced with specimens of brass, gold-plated copper, tinned copper and tinned brass. The spread results are shown in Fig. 2, which illustrates dihedral angle of wetting, spread uniformity, and area of de-wetting*. In computing net areas, areas of de-wet were subtracted.

The solders were also tested on grooved specimens, the degree to which each solder advanced along the groove being noted. Results duplicated those of the prior tests.

As for selection criteria, the noncorrosive flux which produced the brightest and largest spread, with feathered edges of low dihedral angle, was considered to be the flux most capable of reducing metal oxides, lowering solder surface tension, and assuring high probability of intermetallic formation between the solder and the base metal.

*"De-wetted" areas are those covered by the molten blobs of solders which are subsequently uncovered when the solder freezes and shrinks because there is insufficient contact between the solder and the metal specimen.

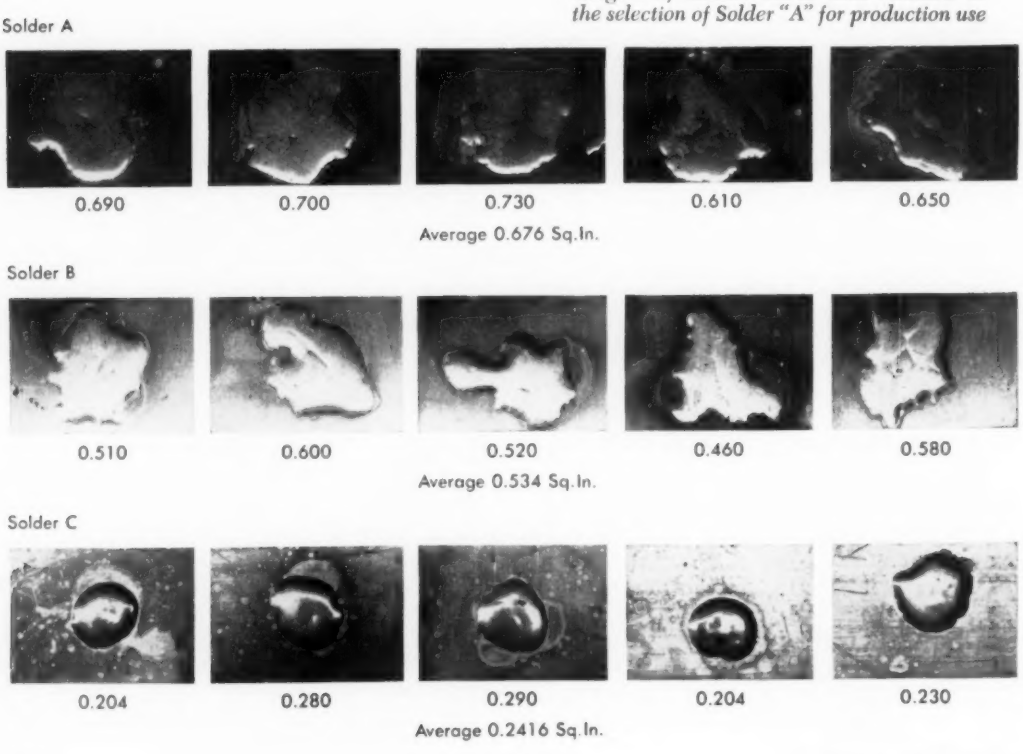
Results of the Tests

One solder (0.032 in. diameter, 60-40 tin-lead wire, and 2.5% rosin flux) showed best in the solder spread test. Termed Solder "A" in Fig. 2, it was 25% better than the solder being used at Martin-Orlando before the investigation.

The solder selected not only made stronger joints, but also made difficult tinning jobs simple. For example, a large terminal post can now be soldered with fewer additions of solder to the connection. Why? Wetting is more uniform; this enables the solder to spread more rapidly. Soldering is faster and the operator has a closer control on quantity.

With the solder we chose, nickel-coated, high-temperature wire can be soldered faster than with most other solders. And the reliability of tinned connections is improved considerably. In fact, high-temperature wire, considered unsolderable in the past and thus often rejected, can now be handled with ease.

Fig. 2 – Results of Solder Tests. Though the metallic composition of the three solders was the same (60% tin, 40% lead), the quality of the rosin core caused significant variations in the total area covered by given weights of solder. These tests resulted in the selection of Solder "A" for production use



Shown is a Drever Gas-Fired Strip Belt Conveyor Furnace for reducing and drying copper powder at the rate of 10 tons per 24 hours at 1000°F.

In the foreground is a Drever Inert Gas Generator for supplying the necessary gases to purge the furnace entry and exit areas.

CONTINUOUS REDUCTION AND DRYING FURNACES

for metal powders

In the manufacture of metal powders, an essential step is the ability of a furnace to completely reduce and dry metal powders and obtain powder of uniform particle density. Experience proves Drever Strip Belt Conveyor Furnaces meet these rigid specifications.

Completely integrated sheet belt furnaces are available for treating oxides of nickel, iron, copper and tungsten. Powder is received from a hopper, leveled on belt and conveyed through a highly reducing atmosphere in the heating and cooling chambers.

Specially designed roll seals keep furnace openings tight while the areas are purged with inert gas. Complete temperature control as well as product uniformity is inherent in the design of these furnaces. They are available for fuel firing, radiant tube or electric heating.

DREVER COMPANY

RED LION ROAD and PHILMONT AVE.
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ENGINEERING AND MANUFACTURING FACILITIES AROUND THE WORLD THROUGH ASSOCIATES IN FRANCE, GREAT BRITAIN, GERMANY, ITALY, JAPAN AND INDIA

35

Circle 1504 on Page 48-B

CORRESPONDENCE INVITED ON ANY METALLURGICAL SUBJECT

LETTERS TO THE EDITOR

Diallyl Phthalate as a Mounting Material

DARTMOUTH, N.S.

In my article on "Improved Metallographic Techniques . . . Diallyl Phthalate as a Mounting Material" (*Metal Progress*, January 1961, p. 121), I neglected to give the names and addresses of the three companies which supplied the diallyl phthalate resin used in our tests. Since diallyl compounds are relatively new in the commercial molding field, this list of suppliers may be helpful:

Food Machinery and Chemical Corp., San Jose, Calif.

Mesa Plastics Co., 11751 Mississippi Ave., Los Angeles 25, Calif.

Acme Resin Corp., 1401 Circle Ave., Forest Park, Ill.

C. A. GODDEN
Defense Research Board
Dept. of National Defense

Learn More About Welding

FLUSHING, N.Y.

I wondered as I read the item "Learn More About Welding" (it appeared as part of "Technology Forecast '61" in the January issue of *Metal Progress*) if your readers realize the full significance of the picture which you presented. The failure to use welding to its fullest extent (and in its most useful way) is cutting into the profits of U.S. industry and adversely affecting our position in the world market.

Welding enthusiasts properly boast of the contributions which welding has made to the design and construction of rockets, jet aircraft, nuclear submarines and other modern developments. Similarly their boasts are just about the role of welding in the use of modern metals. Yet in our boasting and in our efforts to find answers to problems in the application of new metals, we are almost totally ignoring 75% of the potential market – the everyday production of the more common materials for which there is now more than 40 years of experience and accumulated research and technology.

Why isn't more carbon steel being welded? What about iron castings? Each new welded building testifies to the economies to be realized, yet welded buildings are still not common. The economy of repairing defects in castings by welding and of making new castings in smaller sections to be joined by welding has been demonstrated many, many times, yet reluctance to take advantage of these economies is still encountered.

Even where welding is used, its fullest advantages are lost under restrictions which were imposed in its earliest days and have never been changed to reflect our knowledge and experience as of today. Too often, when I see the conditions under which welding is used and the endless restrictions, I think of the man who wears a belt and suspenders and then walks around with his hands in his pockets! Quite often the requirements are not only burdensome and costly but are in fact detrimental and only give false security.

In day-to-day production, not supported by government funds, industry is being pressed to maintain its profit position and overcome rising costs and increasing competition from abroad. The savings of material, time and labor (including the labor to make and handle the extra material) which can be realized by welding is an important factor in the profit outlook – if it is used properly.

SIMON A. GREENBERG
Industrial Consultant

Defects That Nondestructive Tests Can Find

Unfortunately, some errors of omission crept into the picture article of the above title on p. 76 to 79 of the February 1961 issue. For example, proper credit for the source of Fig. 15 and 16 was not given; both came from "Tool Steel Trouble-Shooter", a book published by Bethlehem Steel Co., Bethlehem, Pa. Other information omitted was the photo magnification. The respective magnifications for the micrographs are: Fig. 1, $\frac{3}{8}\times$; Fig. 2, $\frac{1}{3}\times$; Fig.

VALUE ANALYSIS FACT SHEET

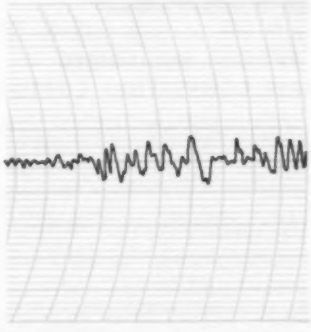
Formbrite Drawn Brass Parts

How to open finishing room bottlenecks and cut polishing costs up to 50%—produce stronger, more scratch-resistant parts—and get additional savings —with Formbrite, superfine-grain drawing brass.

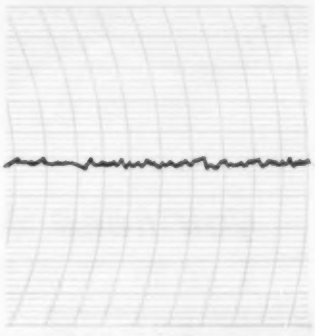
Very often in the production of drawn brass parts which are to be plated or lacquered, finishing costs are greater than those of all preceding operations —or even the cost of the metal. Under any circumstances, they are a high percentage of total costs.

Furthermore, parts go through the pressroom a lot faster than they can through the finishing room, creating bottlenecks in production.

ENLARGED SURFACE TRACES at the right prove that you can lick both cost and time problems with Formbrite®, Anaconda superfine-grain drawing brass. Savings in polishing costs reported by users run from 40 to 50%. These are net savings, as Formbrite costs no more than ordinary drawing brass.

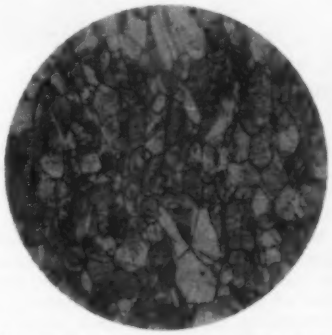


Enlarged surface trace of standard drawing brass (grain size, .045 mm) after 40% elongation. This kind of roughness causes "orange peel" effect in the working of standard drawing brass. Smoothing such mountains down to the valleys takes considerable cutting.



Enlarged surface trace of Formbrite drawing brass (grain size, .005 mm) after 40% elongation. Surface smoothness after deformation is the test of a drawing brass's polishing characteristics. It is relatively easy to level these little hills on the surface of Formbrite. In many cases, users find they eliminate cutting operations altogether, need only a simple coi · buff.

STRONGER, MORE SCRATCH RESISTANT. Formbrite is stronger, harder, springier than the usual drawing brasses in the same standard tempers, yet retains remarkable ductility for forming and drawing, and takes sharp, clean-cut ornamental die impressions. The harder surface means fewer rejects from scratching and marring during handling. In some instances, the superior strength and hardness of Formbrite make possible the use of a thinner gage metal, with an additional saving in material cost.



This is the microstructure, shown 75x, of the standard drawing brass used above.

This uniform superfine-grain structure of Formbrite, shown 75x, is produced by special procedures for rolling or drawing and annealing developed by Anaconda American Brass Company.

SIZES AND TEMPERS. Brass manufactured by the Formbrite method, with its special characteristic of superfine-grain structure, is supplied in standard Formbrite temper, half-hard, three-quarter-hard, hard, and extra-hard tempers, and can be rolled in heavy coils to .004" in thickness by 24" wide, weighing 100 pounds per inch of width. The table below gives physical data and terminology for Formbrite tempers.

ALLOYS. In addition to 70-30 brass, the following Anaconda alloys also are produced by the Formbrite method: Yellow Brass-59, Gilding Brass-4, Commercial Bronze-14, Red Brass-24, and Low Brass-32.

TECHNICAL ASSISTANCE. For help in selecting the alloy and temper to handle your particular job—for a copy of Publication B-39 with more details about Formbrite—see your Anaconda representative. Or write: Anaconda American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 6145

TERMINOLOGY FOR FORMBRITE TEMPERS

TENSILE STRENGTH LB. SQ. IN.		ROCKWELL B HARDNESS		DESIGNATION TO BE USED
MIN.	MAX.	MIN.	MAX.	
49,000	59,000	40	65	Yellow Brass—Formbrite
57,000	67,000	60	77	Half-hard Yellow Brass—Formbrite
64,000	74,000	72	82	Three-quarter-hard Yellow Brass—Formbrite
71,000	81,000	79	86	Hard Yellow Brass—Formbrite
83,000	92,000	85	91	Extra-hard Yellow Brass—Formbrite

FORMBRITE

Superfine-grain drawing brass

a product of

ANACONDA®

Anaconda American Brass Company

Circle 1505 on Page 48-B

LOOK FOR THE DIAMONDS—SIGN OF FINISHING QUALITY

for protection on light metals

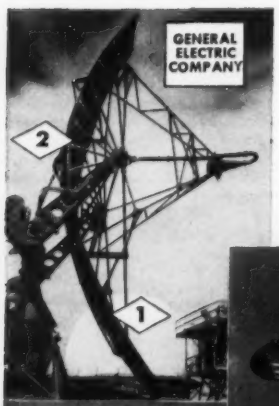
you need IRIDITE

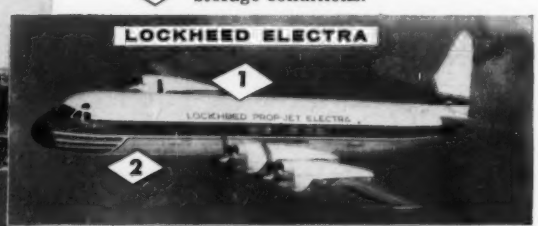
PROCESS ENGINEERED CHROMATE CONVERSION COATINGS

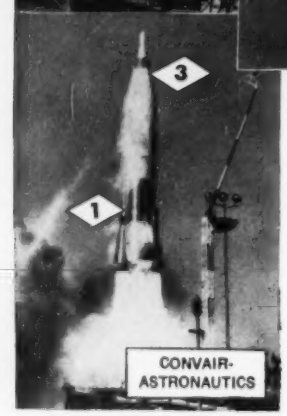
1 Iridite protects against high altitude weather extremes and against corrosion by hydrocarbon fuels, such as gasoline and kerosene.

2 Iridite provides a highly protective non-porous paint base.

3 Iridite protects against corrosive storage conditions.







And, Iridite gives you these additional advantages:

ON ALUMINUM—needs only normal precleaning. Film withstands cold forming or bending. Easily heliarc welded. Unusually low electrical resistance. Clear, yellow or dye-colored finishes.

ON MAGNESIUM—short immersion, room temperature solution, no electrical equipment. Corrosion protection relatively unaffected by high drying temperatures. Applicable to all alloys. Low electrical resistance. Color ranges from light gray to dark brown.

IRIDITE—a specialized line of chromate conversion coatings for non-ferrous metals. Easily applied at room temperatures with short immersion, manually or with automatic equipment. Forms a thin film which becomes an integral part of the metal. Cannot chip, flake or peel; special equipment, exhaust systems or highly trained personnel not required.

For complete information on Iridite, contact your Allied Field Engineer. He's listed under "Plating Supplies" in the yellow pages. Or, write for FREE TECHNICAL DATA FILES.

Iridite is approved under government and industrial specifications.

Allied Research Products, Inc.

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BRANCH PLANT: 400 MIDLAND AVENUE • DETROIT 3, MICHIGAN
West Coast Licensee for Process Chemicals: I. H. Butcher Co.
European Agent: Stora Gronberger, Storgatan 10, Stockholm, Sweden
Chemical and Electrochemical Processes, Anodes, Rectifiers, Equipment and Supplies for Metal Finishing

IRIDITE® Chromates | IRILAC® Coatings | ISOBRITE® Brighteners | ARP® Supplies | WAGNER Equipment

Circle 1506 on Page 48-B

Letters . . .

3, 20 ×; Fig. 4, 50 ×; Fig. 5, 100 ×; Fig. 6, 75 ×; Fig. 7, 75 × Fig. 8, 100 ×; Fig. 9, 1/10 ×; Fig. 10, 1 ×; Fig. 11, ¾ ×; Fig. 12, ⅓ ×; Fig. 13, 1/5 ×; Fig. 14, 100 ×; Fig. 15, 1/5 ×; and Fig. 16, 1/6 ×.

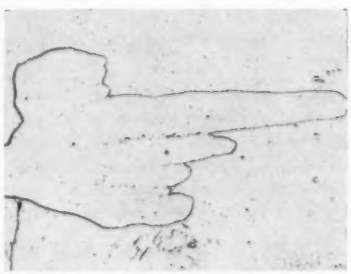
A Definition of Scope

IJMUIDEN, NETHERLANDS

In the November issue of *Metal Progress*, Tom Bishop presented a comprehensive discussion of the meeting held jointly by the International Deep Drawing Research Group and the Société Française de Métallurgie in Paris last May (see "Formability Tests for Sheet Metal", p. 95). However, in the definition of the scope of the I.D.D.R.G., he says it "seeks to achieve closer international cooperation in the testing of sheet metal for formability and to arrange faster standardization of such tests". Although the arranging of faster international standardization may be a result of the work of the I.D.D.R.G., it is not directly in our scope and cannot properly be included in such a definition.

G. DE WITTE
Vice-President, I.D.D.R.G.
(Koninklijke Nederlandsche Hoogovens en Staalfabrieken N.V.)

He Went That-A-Way



The hand pointing "that-a-way", shown above, was photographed by J. D. Grozier and J. Gross of the core engineering department of the Bettis plant, Westinghouse Electric Corp., Pittsburgh. Discovered during an examination of a nitrided zirconium crystal bar sample, the grain structure is magnified 100 times.

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GAS-FIRED HEAT TREATING AND MELTING FURNACES!

- Pot types for use with salt or lead
- Small tool and shop types for general hardening
- Full muffle types
- Types for all non-ferrous melting
- Large and small oven furnaces
- Oven- and slot-type forge furnaces
- and various others

BACKED BY A 38-YEAR RECORD OF DEPENDABILITY

Write for Ajax-Barkling Catalog 106-A

To Ajax-Hultgren and Ajax-Ankersen salt bath furnaces has now been added the rugged line of Ajax-Barkling oil or gas-fired furnaces for a wide variety of heat treating needs. These Barkling furnaces—widely used in the Midwest for over 38 years—will now be handled and serviced by 20 Ajax sales engineering groups located throughout the U. S.—and backed throughout by the internationally-famous Ajax "know how" of modern heat treating methods, procedures and equipment.

AJAX ELECTRIC COMPANY
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Circle 1507 on Page 48-B

Picture-in-a-minute photomicrography with the AO METALLOGRAPH

focus... SNAP IT

SEE IT... in just 60 seconds

With the AO Metallograph you perform every operation while sitting comfortably at a modern desk. You can take notes, change magnifications, orient specimens, make exposures, all with unbelievable speed and ease. A coupled visual and photographic system makes photomicrography easy and routine.

AO's "Workhorse" Metallograph combined with the Polaroid Land Camera back gives you photographic prints in just 60 seconds. A truly unbeatable combination for quick, precise visual observations and "picture-in-a-minute" photomicrography.

While you examine the specimen through the eyepieces the image at the film plane is focused automatically. You simply snap the shutter...see the Polaroid print in just 60 seconds. This photographic record is permanent, can be filed for review anytime, anywhere.

The Metallograph camera aperture also will accommodate a regular 5" x 7" fixed camera back. In addition to 5" x 7" film, you can use 4" x 5" and 3¼" x 4¼" plates or cut film by means of adapter film or plate holders. For further information mail handy coupon.

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Circle 1508 on Page 48-B

Dry-Hydrogen Brazing...

(Continued from P. 96)

A multipoint temperature recorder is desirable to record the assembly temperature as picked up by the thermocouples. Curves provided by the recorder tell the furnace operator at a glance the heating rate and temperature uniformity of the assembly and enable him to determine accurately the time in the brazing range.

Time at temperature or time in the brazing range normally should be just sufficient for the alloy to flow through the joint. This is sometimes difficult to estimate when light and heavy sections are together. Usually the time must be based on that required to bring the heavy section to full temperature. An excess of time can cause trouble because of grain growth or blushing of the brazing alloy away from the joint.

Cool Fast – Cooling rate for the assembly after the desired time at temperature is generally as fast as possible with consideration being given to the effect of differential cooling. If the furnace is removed while the parts are at full temperature, the areas of the assembly nearest the retort walls will cool first. When components are assembled within other components, the outer portions will cool faster. This causes differential contraction and can produce misaligned assemblies. It can also cause cracks in the braze metal. If differential cooling is likely to be a problem, it is usually advisable to cool in the furnace until the temperature of the assembly is below the solidification point of the brazing alloy. The only objection to this procedure is that the assembly may be in the brazing range long enough to cause grain growth and blushing.

Summary

The major factors which must be considered to obtain good brazing results are listed in the box on p. 96. This list is helpful in working our brazing problems; it indicates the necessity for a thorough engineering job by the product engineer and the metallurgical, furnace and brazing engineers. When such a job is done, unbelievably complicated assemblies can be successfully brazed.

INTERLOX...

a better, lower cost, easily controlled phosphate coating that LOCKS *your finish to the metal.*

Interlox's unusual cleaning ability and radically different type of accelerator produce an even, fine grained, dense coating that literally locks an organic finish to the metal.

Interlox gives you the ultimate in appearance, adhesion and corrosion resistance—no streaks, stains, powdery residue or flash rusting to complicate your production. Interlox baths are unusually long lived and require less replenishment and control.

Extra cleaning power is easily obtained at any time by the addition of a low-cost detergent only. This avoids the danger of over-phosphatizing by the costly practice of adding complete phosphatizing compound when only cleaner is needed.

There is an Interlox product to meet your particular requirements, whether spray or immersion type, single or multiple stage.

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CHEMICAL PRODUCTS DIVISION • CHEMETRON CORPORATION

Circle 1509 on Page 48-B

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PERSONAL MENTION

John Robert Townsend

JOHN R. TOWNSEND retired Dec. 1, 1960, after 40 years of service with Bell Telephone Laboratories, Inc., and is now devoting his time to consultation with the director of the National Bureau of Standards (standardization methods) and the director of defense research and engineering, Department of Defense. As outlined in the biographical appreciation published in *Metal Progress* for November 1957, he began with the Bell System in 1920. In both World Wars he served as consultant or member of various committees advising on war materiel. From 1952 to 1958 he was director of materials and standards engineering for Sandia Corp., the Bell System's (more properly, its Western Electric Co.'s) subsidiary engaged in ordnance work for the U. S. Atomic Energy Commission at Albuquerque, N. M. For the last three years he has been on loan as special assistant to Herbert York, director of defense research and engineering of the U. S. Department of Defense.

Robert H. Nehus – now metallographer for the Kolcast Div. of Thompson-Ramo-Wooldridge, Inc., Minerva, Ohio.

Frederick H. Lovejoy – from president to chairman of the board of Wheelock, Lovejoy & Co., Inc., Cambridge, Mass.

Clarence F. Alban, chief engineer, W. M. Chace Co., Detroit – elected to the board of directors.

Edwin Shuttleworth III, assistant vice-president, Driver-Harris Co., Harrison, N. J. – named assistant sales manager of the company.

William C. Morgan – from sales engineer in the Detroit division of E. F. Houghton & Co., Philadelphia, to the executive staff of the Penn Petroleum Corp., Detroit.

C. Patrick Kenyon – chief metallographer for Sheffield Div., Armco Steel Corp., Kansas City, Mo., retired on Feb. 1 after 33 years of service at the Sheffield steel works, and will now work as consultant in color metallographic, petrographic and macro work for a commercial laboratory with offices in several states.

Carl E. Hartbower – now engaged in welding and mechanical-metallurgy research in the physical metallurgy division of Manufacturing Laboratories, Inc., Cambridge, Mass.

James P. Eagan – from research engineer, North American Aviation, Inc., Columbus, Ohio, to metallographer at the Detroit plant of Jones & Laughlin's Stainless and Strip Div.

Robert F. Jones – from sales trainee at the Cambridge, Ohio, research center of Vanadium Corp., of America, to district representative with Vanadium's Cleveland office.

Richard N. Wardell – now a patent attorney at the Corning Glass Works, Corning, N.Y.

Henry L. Burghoff – from assistant director to director of the research and development department of Chase Brass & Copper Co., Waterbury, Conn.

David E. Huber – now president and director of engineering of Imagineering Enterprises, Niles, Mich., an engineering tests and service laboratory which he organized.

John J. O'Conner – from manager of production planning at the Detroit plant of Jones & Laughlin's Stainless and Strip Div. to division manager of production planning.

Edward J. Stofka – from Carborundum Co., Niagara Falls, N.Y., to Westinghouse Bettis Atomic Plant in Pittsburgh.

Robert B. Lloyd – transferred from Indianapolis, Ind., to Houston, Tex., as area sales manager for Haynes Stellite Co., a division of Union Carbide Corp.

John B. Guthrie, Jr. – now sales manager for Phoenix Rheinrohr Corp., New York, a subsidiary of Phoenix-Rheinrohr A. G., Düsseldorf, West Germany.

Raymond E. Jones – from general sales manager to vice-president in charge of sales for the Matthews Corp., Hawthorne, Calif.

Equipment for heating steel bars for forging, one of many products of AM for the heating or melting of metals by Induction.

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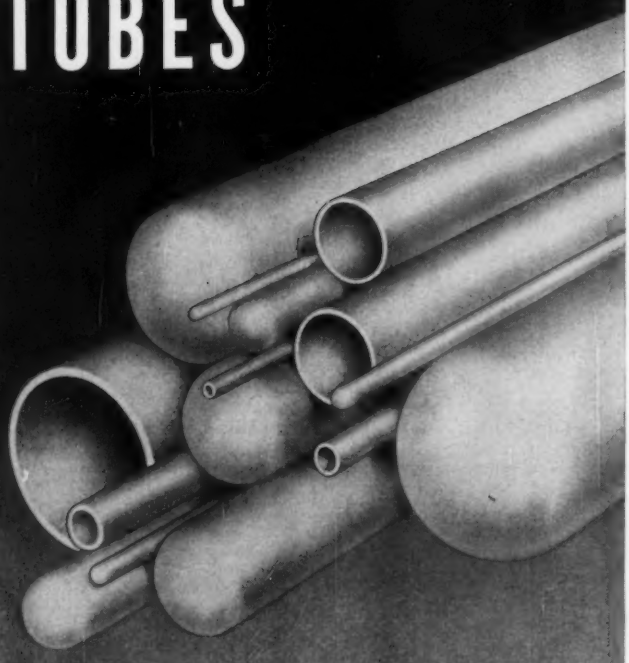
Automatic Heating by Induction for forging an automotive part.

DIFFUSION FURNACE TUBES



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REFRACTORY PORCELAIN COMPANY

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Circle 1511 on Page 48-B

Personals . . .

George Gerard, associate director of the research division of New York University's College of Engineering and research professor of aeronautics – appointed staff director for the academic and research development of NYU's University Valley at Sterling Forest, N.Y., where a major scientific and educational community is planned.

Roy A. Frost – from product metallurgical engineer at the Cambridge, Ohio, research center of Vanadium Corp. of America, to service engineer in engineering sales at the company's Chicago office.

James Fritz – from process metallurgist at the Claymont plant of the Colorado Fuel and Iron Corp., to steel plant metallurgist at the Buffalo (N.Y.) plant.

Elven R. Davis, northwest general manager of Bliss & Laughlin's Sierra Drawn Steel Div. – named to the additional post of general manager, Pacific Coast operations, with headquarters in Los Angeles.

Arthur P. G. McGinnes, Jr. – now manager, product development, for the Beryllium Corp., Reading, Pa.

Roger L. Mogel – now assistant metallurgist, technical services, for Carpenter Steel Co., Reading, Pa.

Norman A. Birch – appointed technical director of the Albion Malleable Iron Co., Albion, Mich.

G. William Bauer – named technical sales manager, Stauffer Metals Co., with headquarters at the Richmond, Calif., office.

Jerome B. Cohen, assistant professor of materials science at Northwestern University – awarded the 1961 Robert Lansing Hardy Metal of the A.I.M.E. in recognition of "exceptional promise" in a man under 30 in the field of mineral beneficiation, in extractive, physical or adaptive metallurgy, and in metal processing.

Edward C. Bayer – now technical director of Holcroft & Co., Detroit.

John E. Krickl – now western district sales manager for Lindberg Engineering Co., Chicago, with headquarters in Downey, Calif.

Steel

Tool Steel Topics

BETHLEHEM STEEL

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Another report on Air-4 tool steel

Blanking and embossing this automotive part, from coiled steel of .125 in. thickness and doing it at substantial speed, is all in a day's work for Bethlehem Air-4 tool steel . . . at Melrath Metal Stamping Corp., Red Hill, Pa. Tool engineers at this plant have several good reasons for giving a good report on Air-4: they like the ease with which it can be machined . . . its simple heat-treatment, and above all, they admire its wear-resistance. Hardened to Rockwell C-60, the die undergoes slight redressing every 100,000 strokes of the press.

HARDENS AT LOW TEMPERATURE

Air-4 is a free-machining, medium-alloy tool steel which hardens in air—at about 1550 F. It has excellent free-machining characteristics because of a lead addition. It also has excellent wear-resistance and high toughness, and is deep-hardening to assure long tool life.

Air-4 is a versatile tool steel. Why not place an order right now for a trial bar, and use it in an experimental run? Your Bethlehem tool steel distributor can give you prompt delivery.

Bethlehem Tool Steel Engineer Says:

Always Heat-Treat the Tool Instead of the Thermocouple

Many tool failures can be attributed to the use of improper temperatures during heat-treatment. In many instances, although the thermocouple chart may have indicated proper heat-treatment temperatures, the microstructure of the tool shows that the recorded temperatures were not attained by the tool. This is called "heat-treating the thermocouple, instead of the tool."

It is easy to see why such errors occur, for the thermocouple indicates the temperature at the location of its tip only. Most furnaces have some non-uniformity of temperature. For example, locations near the source of heat are hotter than remote locations. And the bottom tends to be colder than the top. An operator who is on the ball will survey his furnaces to determine what temperature differences are present. This will assist him in selecting the location which will provide the most accurate indication of the temperature of tools heated in each furnace. It will often indicate that more than one thermocouple is needed.

Where a temperature survey is not feasible, the tip of the thermocouple should be placed as near the tools as possible. But avoid locations near the floor, sides, roof, or near the source of heat. Although the thermocouple is accurate, and highly useful, it's by no means foolproof.

Circle 1512 on Page 48-B

Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Welding Engineers Meet in California

Report on the Western Welding Technical Conference presented by the Santa Clara Valley Section of the American Welding Society, October 1960, San Jose, Calif. Additional papers will be discussed next month.

IN THE FIRST PAPER PRESENTED at this meeting George Linnert (Armco Steel Corp.) discussed the welding of stainless steel. He stated that one of the practices sometimes recommended when welding austenitic steels is that of spraying water about 1 in. behind the weld to prevent carbides from precipitating in the heat-affected zone. But quenching, even though it is done almost immediately, has little effect in keeping carbon in solution. Instead, extensive tests have shown that the austenitic stainless steel becomes sensitized within a few seconds after being welded.

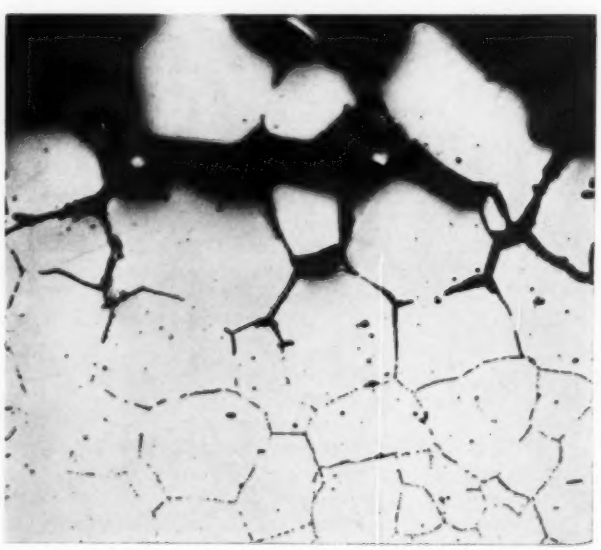
In discussing the welding of stainless steels, Mr. Linnert pointed out that carbide precipitation cannot be cured by selecting a special welding method. It occurs in the heat-affected zones during welding of austenitic stainless steels when these zones are raised to 800 to 1600° F. In this temperature range, carbon migrates to the grain boundaries and precipitates there as chromium carbide. Areas adjacent to grain boundaries are thus depleted of chromium and no longer possess the corrosion resistance of the original alloy. The result is shown in Fig. 1. Figure 2 shows corrosion failure in a pickling basket of Type 304 unstabilized stainless steel. The vertical wires of the basket were sensitized during welding.

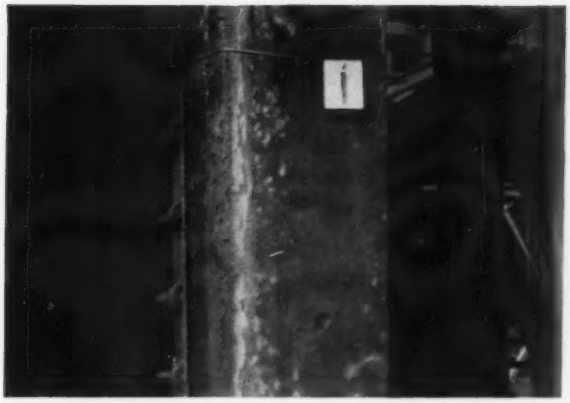
Slow travel speed and low heat input into the weld – conditions which occur during oxyacetylene welding – produce the greatest degree of sensitization in the heat-affected zones; electric arc welding, with its high heat input and greater travel speed, causes less trouble. Mechanized welding equipment with a uniformly fast travel speed is also helpful in minimizing sensitization. But the best way to prevent it is to give the part a solution heat treatment after welding, or to use stabilized or low-carbon grades of stainless steel.

Hot Cracking

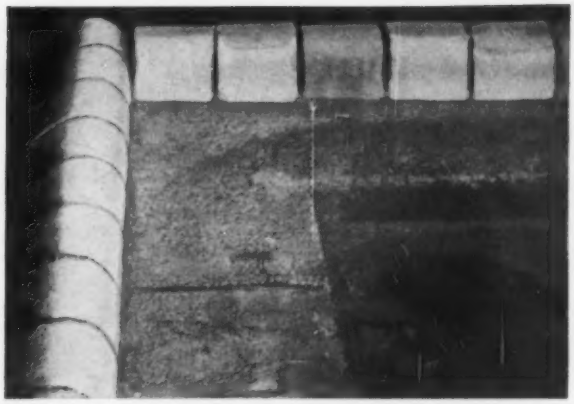
Wayne Wilcox (Arcos Corp.), who spoke on filler materials and processes for welding alloy steels, brought up another problem – hot cracking – which occurs frequently in high-chromium and chromium-nickel stainless steel weld metal unless sufficient ferrite is present. Why ferrite prevents hot cracking in aus-

Fig. 1 – Corrosion in Heat-Affected Zone in Unstabilized Type 304 Stainless Steel

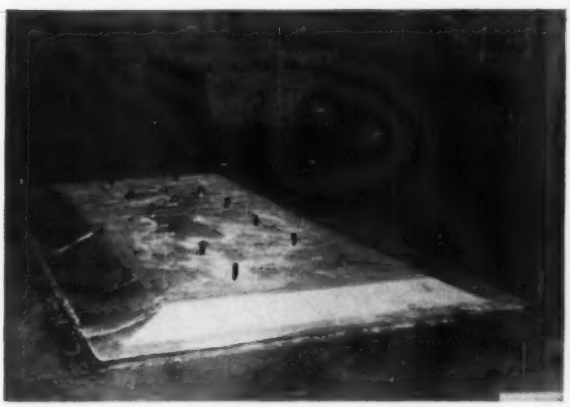




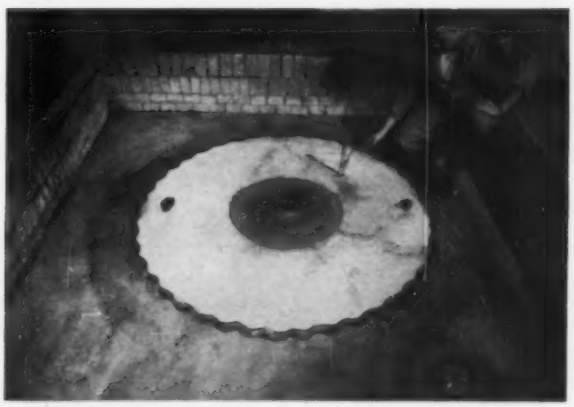
B&W Kaocrete-D, vibrated in place, provides high resistance to the atmospheres encountered in this coke oven door installation. Furthermore, the high erosion resistance and long service life without loss of strength of B&W Kaocrete-D add to its suitability in this application.



A typical monolithic curb wall construction in an annealing furnace using a carbon monoxide atmosphere. The greatly reduced number of joints in which sealing sand can penetrate prevents structural spalling of B&W Kaocrete-A upon heating and cooling. Being monolithic, gas leaks are practically eliminated.



A radiant tube annealing furnace with a base of Kaocrete-A, backed up with Kaolite-20, one of B&W's insulating refractory castables. This furnace operates at approximately 1700 F in a 65% CO atmosphere.



A stack annealing furnace with pedestals cast of B&W Kaocrete-A. The atmosphere is slightly above 8% CO. B&W Kaocrete-A offers strength, volume stability and resistance to carbon monoxide disintegration.

How B&W refractory castables perform in atmosphere applications

One of the difficult problems facing furnace builders and operators in the metals industries is the effect of atmospheres on refractory linings. That's why B&W offers several *specialized* refractory castables for this service, each possessing strength, volume stability and the refractoriness necessary to assure long, trouble-free service.

Take B&W Kaocrete-A, for example. Because of the careful selection and processing of special aggregates and other ingredients with low iron content, this material resists disintegration or other effects produced by high concentrations of CO or H_2 atmospheres. B&W Kaocast and Kaocrete-32 provide the same excellent service at higher temperatures while lightweight Kaolite-20 is outstanding as an insulating castable in atmosphere applications.

B&W Bulletin R-35A gives additional information on versatile B&W refractory castables. Write for your copy of this bulletin to The Babcock & Wilcox Company, 161 East 42nd Street, New York 17, N. Y.

R832

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REFRACTORIES DIVISION

B&W Firebrick, Insulating Firebrick, and Refractory Castables, Plastics, Ramming Mixes, Mortars, and Ceramic Fiber.

Circle 1513 on Page 48-B

tenitic stainless steel welds is not fully known. Usually less than 20% ferrite is desired; above 20%, hot cracking is again experienced.

Alloys containing 28% Cr and higher are ferritic. The 18% Cr, 8% Ni stainless steel, however, can consist of austenite and ferrite. Type 316 stainless steel is unpredictable with regard to the amount of ferrite that will be formed in the weld; the presence of ferrite depends on the base-metal dilution.

Type 405 stainless electrodes, by virtue of their aluminum content and low carbon (0.08% max.), give an all-ferrite weld. The alloy is subject to grain growth, however, and under certain conditions, it can also show brittleness.

Another cause of hot cracking in welds made with high-chromium stainless electrodes is the formation of sigma phase. This hard, brittle constituent occurs in both partially and fully austenitic stainless steel welds containing 18% or more chromium. It appears to form more rapidly in a partially austenitic weld. The higher the chromium content, the more rapidly sigma forms.

When sigma phase is likely to be a problem in welding stainless steels, and fully austenitic welds are required for the application, it is advisable to weld with an austenitic stainless electrode which contains 4 to 6% ferrite, then heat treat the part to take ferrite into solution.

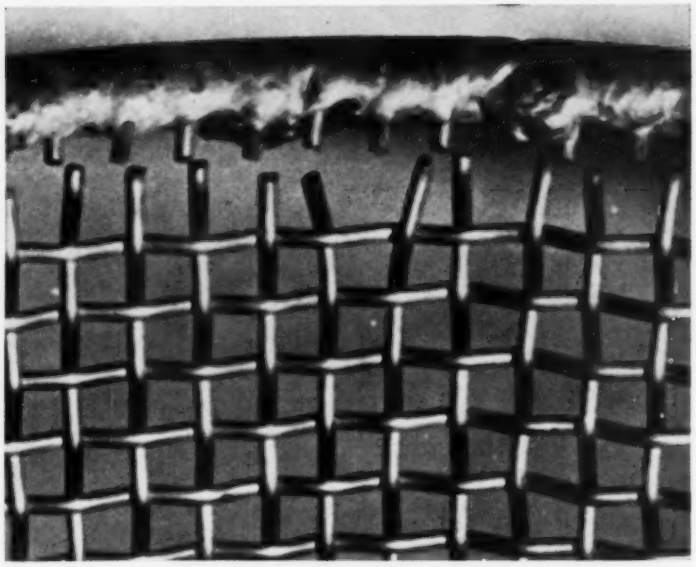

Fig. 2 — Failure in Type 304 Pickling Basket Caused by Sensitization of Vertical Wires When They Were Welded to the Ring Frame

Silicon, often added to an electrode to increase fluidity, also causes hot cracking; its effect is offset by increasing the carbon content of the electrode.

In metal arc welding of low-alloy and stainless steels with coated electrodes, the low-hydrogen types are used exclusively. One type of low-hydrogen electrode consists of an alloy core wire with small alloy additions made in the coating to compensate for those lost from the core wire during welding. Another type uses a carbon steel core wire in which all of the alloy additions are made in the coating. In some instances, metal powders are added to the coatings to supply the required alloying elements.

Welding with coated electrodes has a disadvantage in that the welding rate is slower than that of automatic welding. The equipment is more flexible and is not as cumbersome. Furthermore, the composition of the weld can be controlled by alloying elements in the coating.

In the submerged-arc welding

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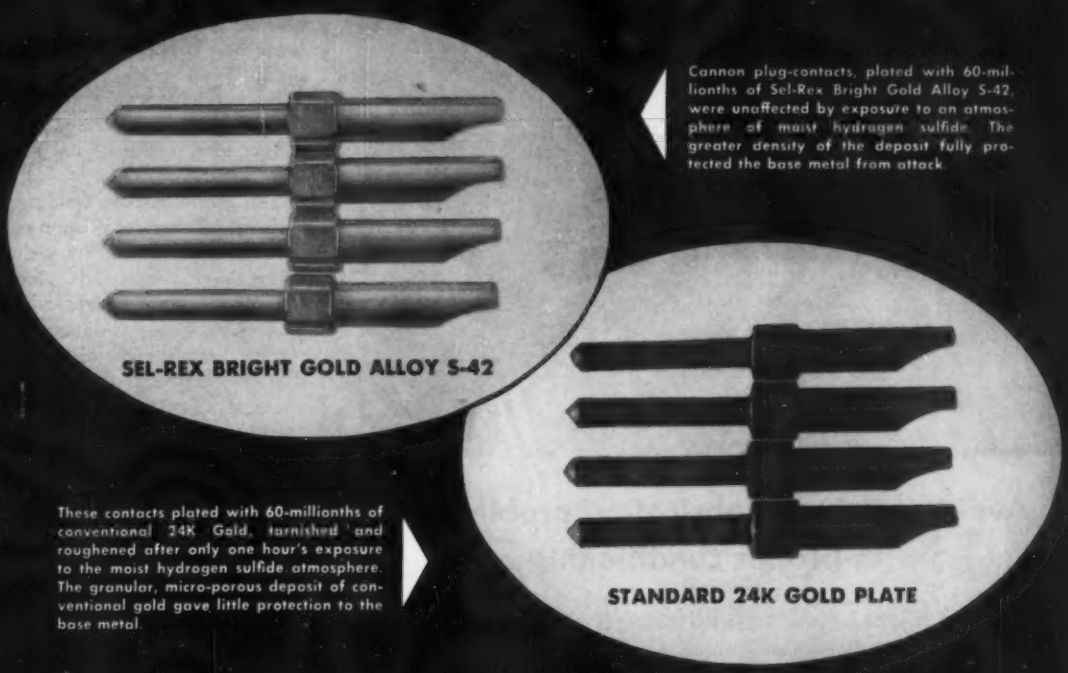
Circle 1514 on Page 48-B

CANNON ELECTRIC improves contact performance with SEL-REX Bright Gold Alloy S-42


Cannon plug-contacts, plated with 60-millionths of Sel-Rex Bright Gold Alloy S-42, were unaffected by exposure to an atmosphere of moist hydrogen sulfide. The greater density of the deposit fully protected the base metal from attack.
SEL-REX BRIGHT GOLD ALLOY S-42
These contacts plated with 60-millionths of conventional 24K Gold, tarnished and roughened after only one hour's exposure to the moist hydrogen sulfide atmosphere. The granular, micro-porous deposit of conventional gold gave little protection to the base metal.
STANDARD 24K GOLD PLATE

Contacts used in world-famous Cannon Plugs must be capable of withstanding corrosion and tarnish, in addition to the punishing effects of repeated engagement and disengagement. The photographs, taken by Cannon in their own laboratory, show why conventional 24K gold plate failed to meet the requirements of this application.

Both samples were plated with 60-millionths of gold over silver plate, and were photographed after an hour's exposure to an atmosphere of moist hydrogen sulfide. The contacts plated with 24K gold tarnished and roughened – those plated with Sel-Rex Bright Gold Alloy S-42 retained their original mirror-bright finish.

Says Cannon Electric Company, Los Angeles: "Our brass contacts plated with Sel-Rex Bright Gold Alloy S-42 offer exceptional protection against both corrosion and friction-wear. Some of the advantages we have demonstrated in our own laboratory, and what they mean to us, follow:

"**1. Greater Hardness:-** Knoop 140-160 for Sel-Rex Bright Gold Alloy S-42, compared to only 40-50 for conventional 24K gold plate.

"**2. Greater Wearability:-** The S-42 deposit is smooth and bright. This, in combination with hardness, means that less force is required to separate the mating halves of the connector . . . less wear, less tendency for galling."

"**3. Improved Reliability:-** Ordinary 24K gold plate is quite granular and exhibits considerable micro-porosity. Tarnish, corrosion of the base metal and early failure in-service of the plated contact is the end result. The Bright Gold Alloy S-42, being a smoother, far more dense deposit, has demonstrated much greater protection against tarnish and corrosion in all the tests we have performed at Cannon.

"At Cannon Electric, Sel-Rex Bright Gold Alloy S-42 has been instrumental in solving wear and tarnish problems encountered in connectors used in aircraft, and intricate missile and electronic components."

The foregoing is just another of our many case histories which prove that: "From Missiles and Rockets to Misses and Lockets – there's a Sel-Rex Precious Metal Plating Process to help you make your product better, more salable."

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Circle 1516 on Page 48-B

Welding . . .

process, the electrode is submerged in the flux while welding is in progress. Three types of fluxes are used. The neutral flux contains no alloy additions. One type of flux contains alloying elements to compensate for those lost in the arc. Another type of alloy-reinforced flux is used to alter intentionally the composition of the core wire during welding. Larger alloy additions are made in this instance.

The submerged-arc welding process allows better deoxidation control, and can be employed for welding a wider range of materials. Inert gas or carbon dioxide gives additional protection against oxidation.

The disadvantages of this process are that extensive flux handling is necessary. Some stainless steel alloys, for instance, cannot be welded, and it does not lend itself to a great variety of welding positions.

Another process, inert-gas-shielded welding, has the advantage of high versatility in many welding positions because small hand guns can be used. Certain metals, such as Type 321 stainless steel, aluminum and titanium, can only be welded by this technique.

The disadvantages of this process are that certain areas of the weld and heat-affected zones are not protected against oxidation by the inert-gas shield. Also, the alloy content must be in the welding wire unless tubes are used with metal powders inside. The weld bead has no slag protection to prevent it from oxidizing while it is still hot after the gas shield has passed on.

With the electroslag process, welds can be made at a very rapid rate. Joint preparation is not critical and smaller quantities of weld metal are required to produce the joint. Disadvantages include large columnar grains in the weld and a wide heat-affected zone.

Filler Metals

In filler metals, especially those for 4340 and HY-80 steels, an attempt is made to keep sulphur, phosphorous and silicon low. Carbon and manganese are usually kept on the high side of the range.

Austenitic stainless steel electrodes can be used for welding alloy steels where heat treatments are not re-

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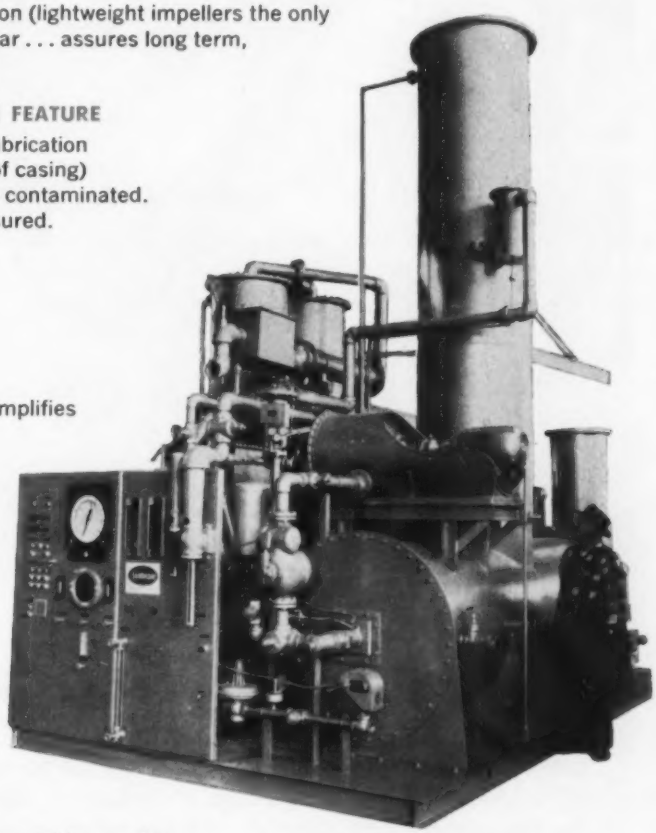

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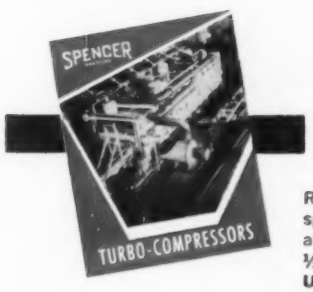

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Circle 1517 on Page 48-8

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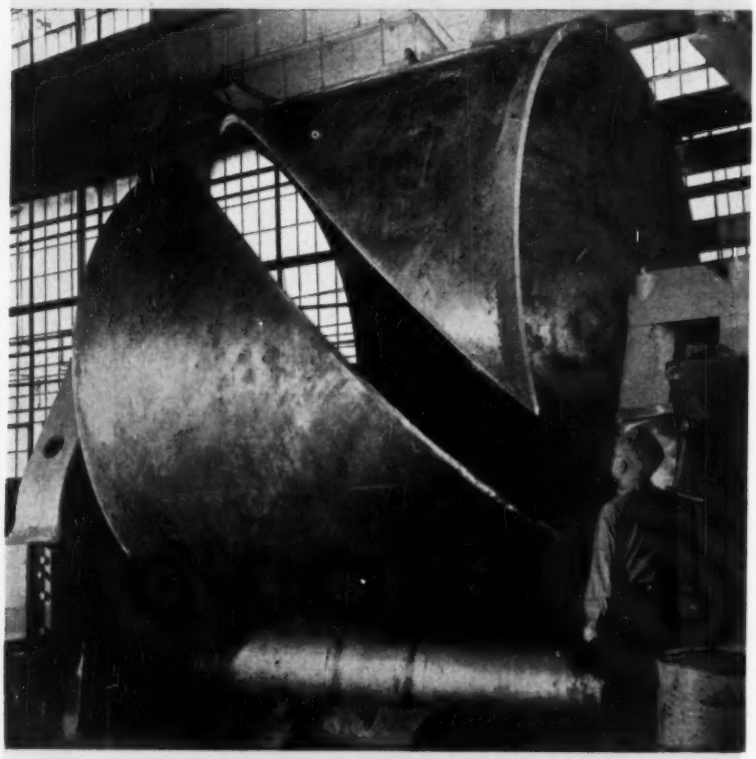

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Circle 1518 on Page 48-B

Welding . . .

quired after welding, and where preheat is not desired.

The current trend in welding electrodes is toward matching the weld metal composition with that of the base metal (particularly when heat treatment is required), rather than use a dissimilar metal electrode to obtain certain properties. The latter is typified by the use of a 5% Cr steel electrode to obtain greater hardenability in a weld. (The base metal in this instance could be a 4 to 6% Cr alloy steel.)

To increase notch toughness at low and high temperatures, coatings of high lime content are better than those of high titanium for low-alloy steel electrodes. In austenitic stainless steel electrodes, lime coatings offer no advantage over titanium coatings as far as increased notch toughness is concerned.

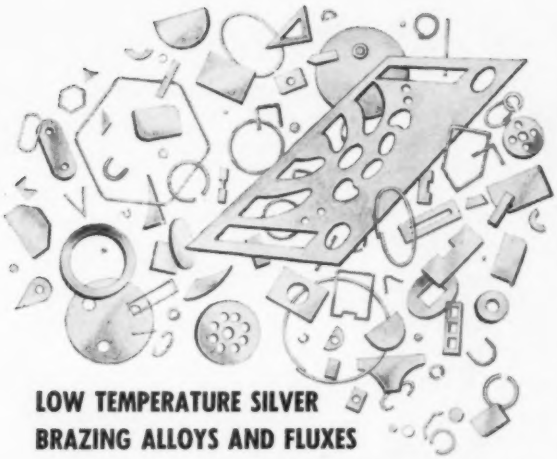
The use of iron powder in electrode coatings does not add any more weld metal than the solid alloy electrode with no powder in the coating, according to Mr. Wilcox. Metal powders have their main use in coatings to produce alloy additions in the weld.

In stainless steel electrodes, extra low carbon minimizes carbide precipitation, but also decreases yield strength of the weld.

Precipitation-Hardening Steels

Other tips on welding the stainless steels – specifically the precipitation-hardening types – were presented by George Linnert. He pointed out that, despite its 2 to 5% Cu content, 17-4 PH welds in a manner very much like the conventional chromium-nickel stainless steels. The copper is not lost by oxidation during welding, and is present in a form that does not interfere with weld ductility. Sound joints free from porosity and cracking result.

The very low carbon content of 17-4 PH precludes underbead cracking in the heat-affected zone, even when preheat is not used. To obtain ductility, the composition of weld deposits in 17-4 PH must be controlled to result in the correct amount of delta ferrite. A large amount of delta ferrite results in a directional dendritic pattern of that phase through the structure; a coarse cleavage type of fracture and poor elonga-



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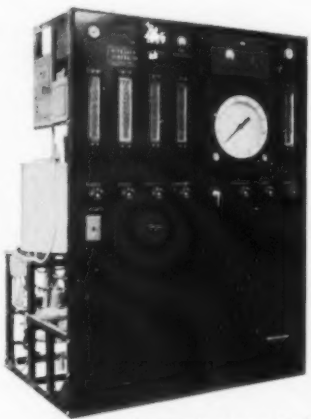

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Circle 1519 on Page 48-B

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Circle 1520 on Page 48-B

Welding . . .

tion results. By adjusting the chromium and nickel content of the weld, ferrite will take the form of small globules (Fig. 3), and a small amount of austenite, which insures good ductility in the weld deposit after heat treating, is retained in the structure. The microstructure results in good strength and elongation in the material and causes a fine shear-type tensile fracture.

In 17-7 PH, the heat of welding austenitizes the heat-affected zone, leaving a soft ductile structure in the as-welded condition. For hardening, the weld must be austenitized carefully to dissolve only a certain amount of carbon. It should be taken to 1750 to 1775° F. to leave some of the carbon (an austenite former) out of the solution in the form of carbide particles. Subzero cooling will then transform the material to a martensitic condition, after which it can be given the precipitation-hardening treatment.

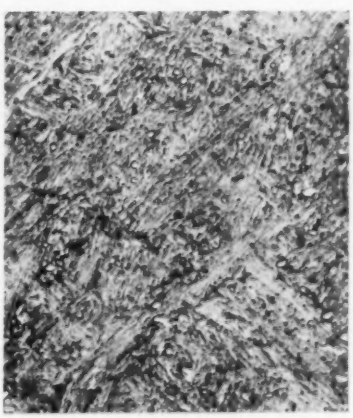

Fig. 3 – Annealed and Hardened (at 900° F.) 17-4 PH Weld Metal. Small amount of delta ferrite (globular) in matrix of martensite, which contains some retained austenite, promotes fine shear-type tensile fracture and good ductility

Porosity has posed no problem in metal-arc welding of 17-7 PH stainless steel. Though it has appeared when the inert-gas tungsten-arc technique has been used, the addition of a small amount of titanium to the alloy gives sound welds.

The aluminum present in 17-7 PH is a powerful ferrite former, and can give as much as 25% ferrite in the

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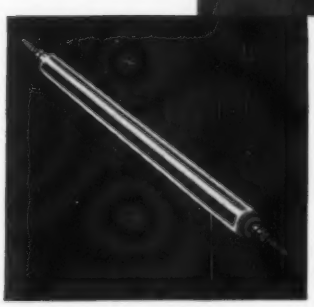

Circle 1521 on Page 48-B

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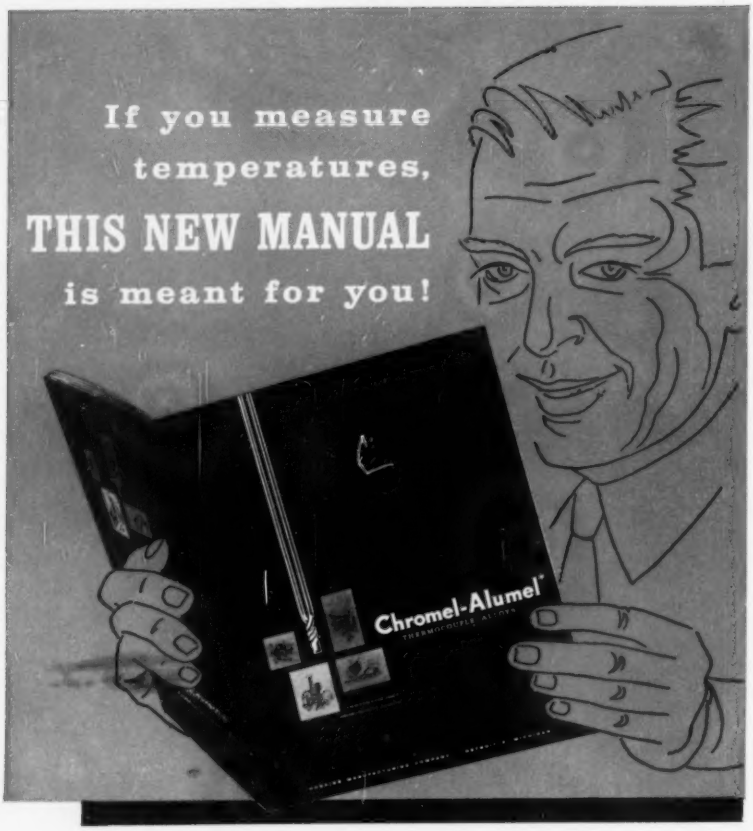

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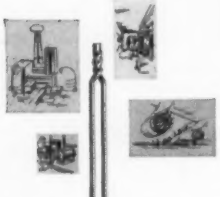

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Circle 1522 on Page 48-B

Welding . . .

weld. After the regular double-hardening treatment (TH 1050) the weld is strong and hard, but its ductility is lower than that of the base metal. Annealing prior to the TH 1050 treatment brings about a small improvement in ductility.

Type 17-10 P stainless steel was designed as a nonmagnetic, hardenable grade. It is basically a 17-7 PH steel with 10% Ni and about 0.12% C and 0.25% P. Unfortunately, when this steel is welded, the phosphorus content causes embrittlement and cracking by forming a complex low-melting compound at the grain boundaries. Cracking in the heat-affected zone cannot be prevented and, at present, Type 17-10 P is not weldable. In research now in progress, it has been found that by substituting manganese for some of the nickel, delta ferrite occurs in the heat-affected zone. The ferrite holds the phosphorus in solution and prevents the formation of the brittle phosphide. This variety of 17-10 P stainless steel is not yet commercially available.

Welding Nickel Alloys

A new electrode composition has recently been developed by the Navy for welding nickel and nickel-base alloys in all positions. This electrode, which was described by Ken Spicer (International Nickel Co.) in his talk on the welding of nickel alloys, is a 4 N-85 type. It has the normal chromium and iron content of an Inconel electrode and contains, in addition, 2% Cb. It leaves 6 to 8% Mn in the weld deposit. Manganese is the key element which makes the new electrode superior to the Inco "A" composition as an all-purpose electrode for welding nickel and nickel-base alloys to themselves and to dissimilar metals. In joining Inconel to mild steel, for example, this new electrode results in less cracking and less porosity than previous all-purpose nickel-base electrodes. Welds possess the same strengths as those of base metals.

Another new electrode for MIG welding is designated EN-87 (MIL-E 21562), a designation soon to be changed to ERN-87. This electrode was developed for use in overlaying for nuclear service. It is also high

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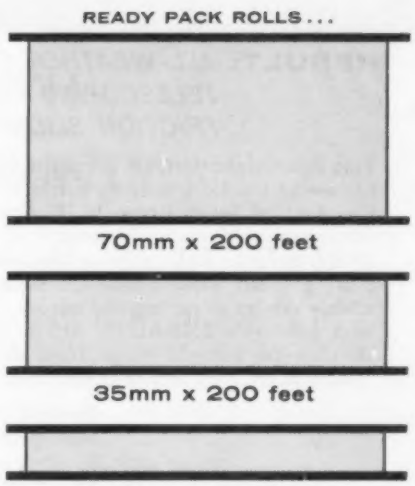

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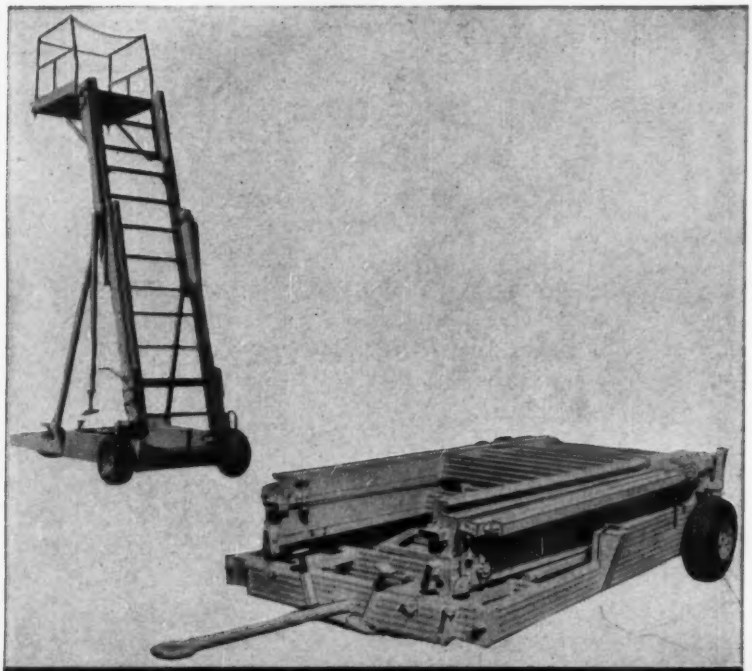
X-ray Sales Division, Rochester 4, N.Y.

Circle 1523 on Page 48-B

LUBRICATION REPORT

(TFE coating)



Application: *Portable Aircraft Maintenance Stand Lubrication.*

Problem: *To Minimize sliding friction at widely varying temperatures.*

Solution: *'EMRALON'® 310 (a tetrafluoroethylene pigmented, bonded film lubricant) spray-applied and baked at 300° F. for one hour.*

RESULT: *ALL-WEATHER COATING GIVES TELESCOPING STAND NEEDED LOW-FRICTION SLIDING SURFACES*

This lightweight portable aircraft maintenance stand was developed for use by the U. S. military forces by South River Metal Products Co., Inc., of South River, N. J. Approximately 40 lineal feet of telescoping surfaces are contained in the stand which elevates to 13 feet for use, and compacts to a height of only 2 feet for transporting. Tests showed that the sliding magnesium sections were readily subject to galling and seizure. The dry-film coating obtained with Acheson's 'EMRALON' 310 provides the necessary lubrication through an ambient range from desert heat to Arctic sub-zero temperatures . . . and does not cake, evaporate or freeze.

Perhaps one of Acheson's series of TFE coatings can help solve your dry-film lubricating problem. Write for 'EMRALON' 310 or 'EMRALON' 320 (air dry) Product Data Sheets. Dept. MP-41.

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ACHESON Colloids Company

PORT HURON, MICHIGAN

A division of Acheson Industries, Inc.

Sales offices in principal cities.

Also Acheson Industries (Europe) Ltd. and affiliates, London, England

Circle 1524 on Page 48-B

Welding . . .

in manganese, but not quite as high as the 4 N-85 electrode.

Ductility of Nickel Alloys

An important factor to consider when welding age-hardenable nickel-base alloys is the relationship of ductility to temperature. Each of the alloys in this class shows low elongation in a particular temperature range, and in some instances stresses induced during welding can exceed the yield point of the material in the annealed condition.

If the weld is subjected to high residual stresses and also exposed to temperatures at which its ductility is low, cracking and failure can occur. Before welding and heat treating these alloys, the temperature range of low strength must be known, and the weld should be heated rapidly through this range.

A recommended method for heat treating these alloys is to preheat the furnace to a temperature above the region of low ductility, then charge the cold part into the hot furnace. This heats the part through the temperature range of low elongation as rapidly as possible and stresses are relieved before cracking can occur.

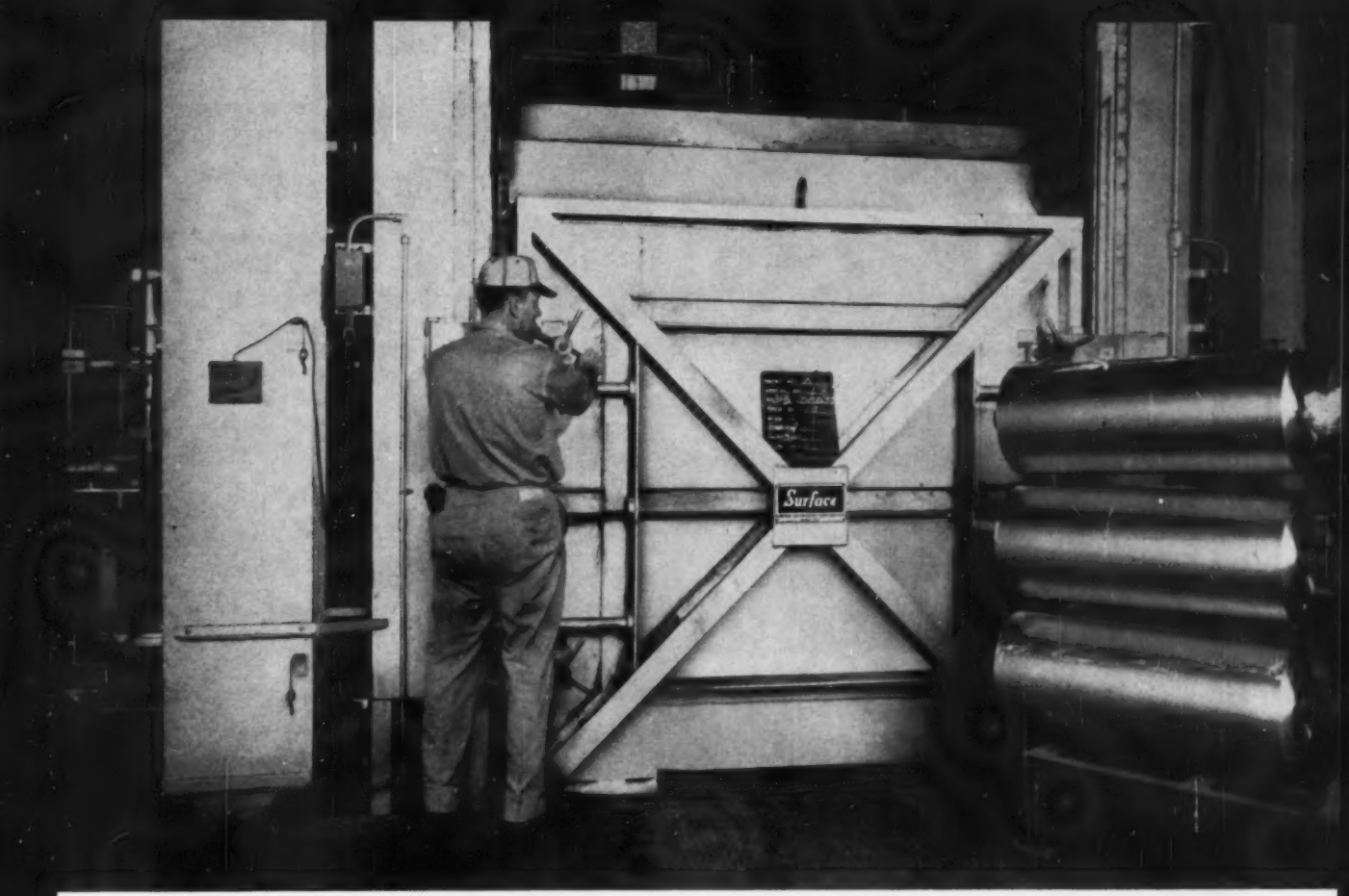
In discussing other factors in the fabrication of high-nickel alloys, Mr. Spicer mentioned that oxyacetylene welding of these materials is now staging a strong comeback in pipeline welding. Submerged-arc welding is not now recommended as a process for welding Inconel.

High-nickel alloys can be resistance welded satisfactorily and, under special conditions, although not usually employed, inert-gas shields can be used. Ultrasonic welding is showing tremendous promise for welding thin, high-nickel alloy materials. This work is being carried on with particular success in the electronics field.

Nickel and high-nickel alloys cannot be cut by ordinary oxyacetylene methods. Iron powder cutting can be used, but inert-gas tungsten-arc cutting is now the preferred process. High-nickel alloys up to 5 in. thick have been cut by this technique.

Welding Conditions

In welding nickel and high-nickel alloys, the joints must be designed



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Phenomenal temperature uniformity (never varying more than 5°) and low costs are the profits earned by Anaconda Aluminum with four of these Surface Power Convection furnaces in their Louisville plant.

Each furnace anneals an 8,000-lb. load of coiled aluminum foil in a seven-hour heating cycle. Coils are stacked on racks, as you see here, and fork-lifted directly into the furnaces. Surface DX® generator gas protects the foil during the cycle.

Power Convection* equipment simplifies furnace construction,—just one fan, minimum furnace size for its capacity. This reduces both first cost and operating maintenance. For more data on Surface Power Convection equipment write for Bulletin SC-182. Surface Combustion, **2377** Dorr Street, Toledo 1, Ohio. In Canada: Surface Industrial Furnaces Ltd., Toronto, Ontario.

*Trademark of Surface Combustion, Division of Midland-Ross Corp.

Surface

A division of Midland-Ross Corporation

Circle 1525 on Page 48-E

Time-tested equipment . . .
plus progressive engineering . . . to meet
your heat-treating requirements
Progressive things are happening at Hones to bring together the experience of years in industrial heating equipment and the forward-looking concepts of modern engineering skills. The time-tested "Buzzer" line needs no blowers, power or other auxiliary equipment to effect combustion; simply connects to the available gas supply.
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MANUFACTURERS OF "BUZZER" EQUIPMENT FOR HEAT TREATING · MELTING · SOLDERING... SINCE 1911
Circle 1526 on Page 48-B

Welding . . .

with sufficient gap to insure complete penetration. Complete penetration can be obtained in carbon steel in thicknesses up to 1 in. using a square butt joint, but in stainless steels, a section of about 0.1 in. is the thickest through which reliable penetration is obtained using a square butt joint. For welding high-nickel alloys, the joint must be open (a V-joint can be used, for instance) if full penetration is desired.

The angle at which the electrode is held during metal-arc welding can make the difference between success and failure in welding these alloys. The electrode is always carried normal to the weld bead and angled slightly in the direction of welding.

The shielding gas used in inert-gas tungsten-arc welding should be of high purity and should not contain oxygen, nitrogen, carbon dioxide, or hydrogen. If these gases are present, they will cause porosity and other defects. Gas delivery should be regulated to as low a flow rate as possible. If too great, it also causes porosity.

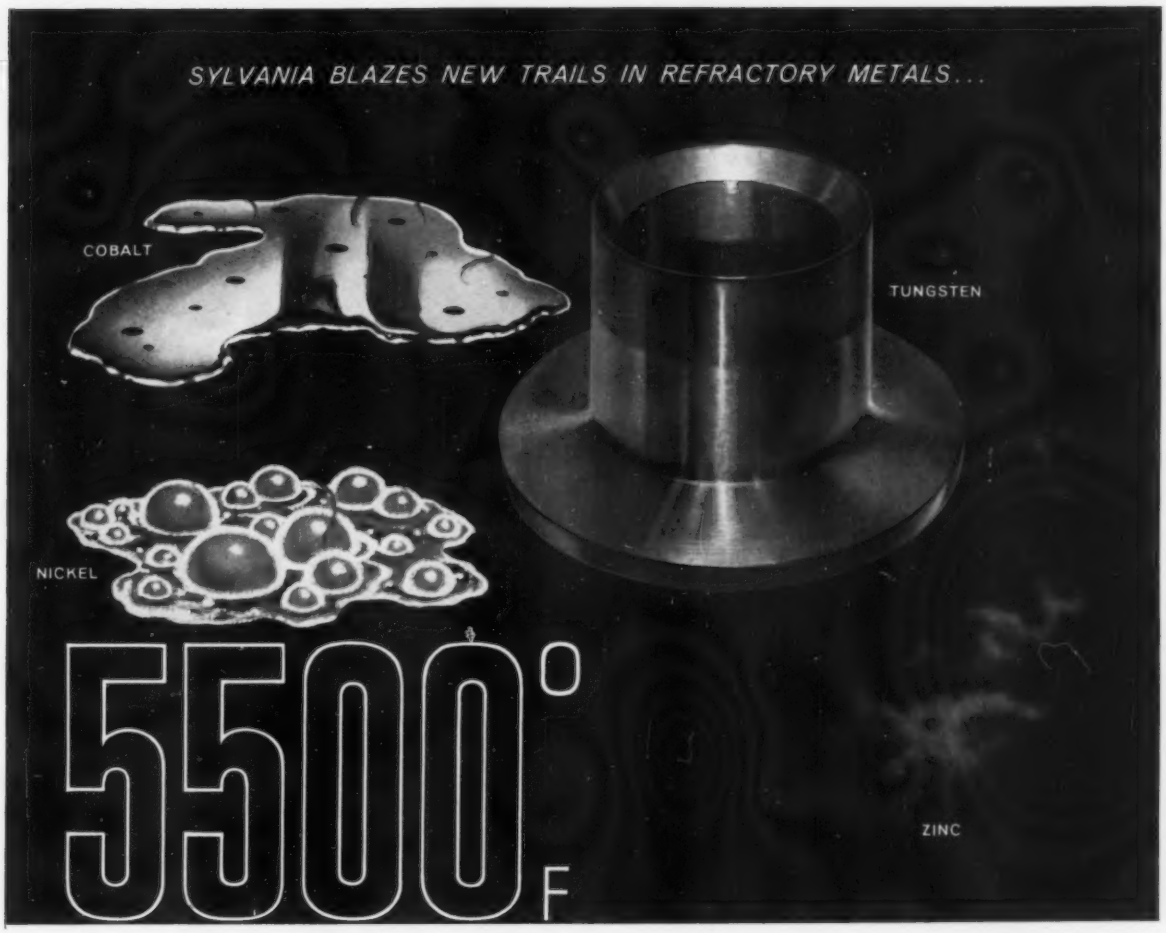
Arc length must be controlled, and should not exceed the cold arc gap set up on the welding machine. Best results are obtained when the cold arc gap is held between 0.020 and 0.030 in.; it must not exceed 0.050 in.

At least 50% of the weld bead should come from filler metal. If too little filler metal is added, porosity will be found in the weld.

When a backup bar cannot be used and the joint is backed up with a flux (on the opposite side of the weld), the flux must be completely dry prior to welding to prevent porosity.

Welding HY-80 and T-1

Both HY-80 and T-1 steels can be readily welded by most processes. In describing the welding of such steels, Daniel J. Snyder (United States Steel Corp.) pointed out that neither of them normally requires preheating for welding because the hard zones adjacent to the weld exhibit the characteristic toughness of tempered martensitic steels. In spite of this, some specifications still call for preheating HY-80 and T-1 (at 200 to 300° F.). *(Cont'd. on p. 142)*



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To make this property pay off for you, Sylvania recently put to work its new isostatic pressing and sintering operation. Through this operation, it can produce tungsten or molybdenum ingots up to 10" in diameter and up to 4 feet long. *Sylvania now produces all four*—billets and ingots for forging, electrodes for arc casting, blanks for machining, or machined blanks ready for your use.

Perhaps you've never considered refractory metals as the answer to your needs. But the same properties that solve the problems of throat inserts for rockets and missiles can pay you dividends in piercing points, boring bars, dies, tools and in countless other ways.

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SYLVANIA

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Circle 1527 on Page 48-E

NEW SUPER-TOUGH ORE HAULER USES

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HIGH-STRENGTH STEEL

TO CUT DEAD WEIGHT AND STRETCH PAYLOAD CAPACITY

This Lectra Haul M-55, made by Unit Rig and Equipment Co. of Tulsa, is now working in the open pit iron mines in Minnesota's Mesabi range. In bone-freezing —40° weather, it can stand up to the shuddering shock of 55 tons of drop-loaded iron ore, climb a 6% grade at 8.6 mph then dump those 55 tons in a crashing, grinding 18 seconds. The quarry body that takes this loading impact and dumping abrasion in sub-zero temperatures is made of N-A-XTRA high-strength steel, with X-A-R Abrasion Resistant Steel for extra hardness and toughness in wear areas. N-A-XTRA also forms the structural members of the complete unit.

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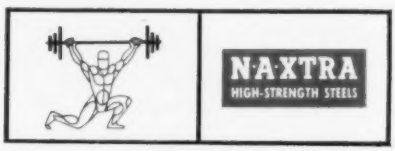

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Design note: Bottom, sides and front of the Lectra Haul quarry body were fabricated of N-A-XTRA 100 (100,000 psi minimum yield strength) from plates ½" thick and reinforced with cold-formed channels of ⅜" thick N-A-XTRA 100. Wear areas of bottom, side and front slopes were made of X-A-R Abrasion Resistant Steel from plates ⅝" thick, 388 Brinell hardness. Fabrication followed standard shearing, gas cutting and welding procedures.

Great Lakes Steel is a Division of NATIONAL STEEL CORPORATION

Circle 1528 on Page 48-B

the ACCURATE WAY to test MICRO and MACRO hardness

Wilson TUKON hardness tester

• Wilson TUKON testers make and measure extremely shallow indentations. They are used, for example, by manufacturers of watches, hairsprings, needles and jewels. In laboratories, TUKON instruments test individual crystals or microscopic particles. On any job, they provide these important advantages:

Accuracy—Precision-built TUKON testers give consistently correct results. Loads are applied without friction or impact—Bausch & Lomb optical equipment is standard—vibration is closely controlled.

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WILSON "ROCKWELL" HARDNESS TESTERS

Wilson Mechanical Instrument Division
American Chain & Cable Company, Inc.
230-F Park Avenue, New York 17, New York
Circle 1529 on Page 48-B

Welding . . .

Welded joints in HY-80 and T-1 steels should be cooled to 200° F. and held at this temperature for 2 to 3 hr. before cooling to room temperature. This treatment completes transformation before the plates reach ambient temperature and thus reduces cracking tendencies resulting from retained austenite.

HY-80 and T-1 should be welded only in the heat treated condition. Otherwise, cracks will occur during subsequent heat treatment.

In welding HY-80 and T-1 steels, low-hydrogen electrodes must always be used to avoid underbead cracking. Before welding, the electrodes must be dried to a moisture content of 0.1%. Even a small amount of moisture in these electrodes will provide enough hydrogen to cause cracking.

If preheating is considered necessary, it must be carefully controlled to avoid changes in the microstructure of heat-affected zones which might result in lower strength and decreased toughness. Multipass stringer bead welding techniques are preferred to avoid overheating in the heat-affected zones.

Electrodes containing vanadium should not be used on these steels if welding is to be followed by stress-relieving. Embrittlement may result.

R. C. BERTOSSA

Conductivity as a Measure of Physical Properties

Digest of "Effect of Specimen Thickness, Cladding, and Lift-Off Adjustment on the Conductivity of 7075-T 6 Aluminum Alloy", by R. A. Chihoski, R. R. Jones, D. Hunter and D. D. Seltzer. Paper presented before the Society for Nondestructive Testing meeting, May 1960, Dallas, Tex.

EXPOSURE OF 7075-T 6 aluminum alloy to elevated temperatures for various periods of time alters the metallurgical structure with the changes being reflected in modifications of conductivity, strength, hardness, and other properties. Changes in conductivity can be used to indicate approximate physical properties of components after various thermal histories such as suspected fire

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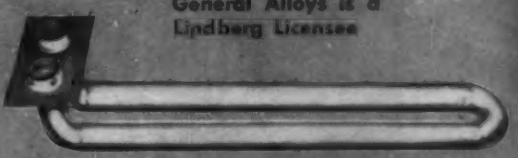

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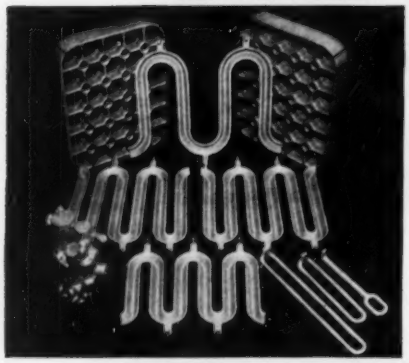
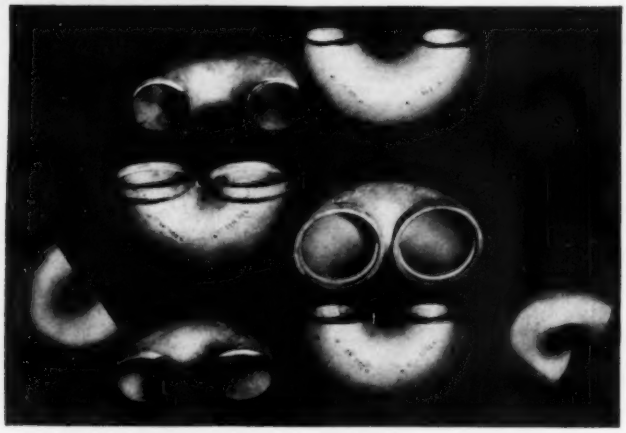
Circle 1530 on Page 48-B

SHELL MOLDED CASTINGS





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If you are looking for quantity deliveries on castings ranging in weight from an ounce or two to several pounds, our shell molding department is at your service. It is backed by nearly forty years broad experience in the high alloy casting field, which covers static and centrifugal castings as well as shell molded.

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CHICAGO OFFICE: 332 South Michigan Avenue

DETROIT OFFICE: 23908 Woodward Avenue, Pleasant Ridge, Mich.

Circle 1531 on Page 48-B

Conductivity . . .

damage or improper processing.

Conductivity measurements were made with a type FM-100 magnatest conductivity meter (Magnaflux Corp.) which uses eddy currents to measure electrical conductivity of nonmagnetic alloys. A probe acts as a "leg" of a bridge with impedance varying as a function of the conductivity of the material on which the bridge is placed. After placing the probe, the bridge is unbalanced. Balance is restored by adjusting the main dial capacitor which then allows direct reading of the conductivity in percent of the International Annealed Copper Standard.

Extreme deviations from true conductivity are quite important since acceptance or rejection of components made from 7075-T 6 aluminum alloy may rely on the conductivity through its conversion to approximate physical and mechanical properties. Sheet thickness, cladding thickness, and "lift-off" adjustment influence the conductivity reading of the instrument. "Lift-off" is the distance of separation between probe and metal surface due to an intervening nonconducting film. An adjustment can be made so that readings on a base metal covered by a film of specific thickness will indicate the true conductivity.

Sheet thickness has no effect on conductivity readings above a minimum thickness which depends on the base material conductivity. For 40% conductivity, minimum thickness is 0.050 in.; for 30% conductivity, minimum thickness is 0.060 in. Still greater thickness is required for metals with lower conductivities.

Cladding gives readings which are greater than the base-alloy conductivity because the clad has a higher conductivity than the base alloy. The effect becomes more pronounced as the clad thickness increases.

Nonconductive films less than 0.0042 in. thick have no significant effect on readings of base material with less than 30% conductivity. Film thicknesses between 0.0006 and 0.0030 in. give readings which are slightly high (less than 1%) on base materials with 30 to 60% conductivity, while low readings are caused by film thickneses greater than 0.0036 in. C. O. SMITH

(More digests on p. 150)

Nothing Is Too Intricate Or Difficult For JARL

From the simplest to the most complex

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Circle 36 on Page 48-B

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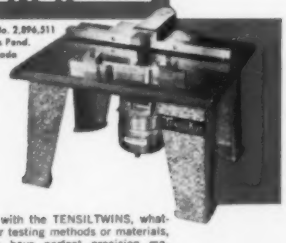

● Now with the TENSILTWINS, whatever your testing methods or materials, you can have perfect precision machined physical test specimens in less than two minutes.

● TENSILKUT precision machines all foil, film, sheet and plate metals . . from .0005" foil to .500" plate. Hard .001 stainless steel foil to soft ½" aluminum, soft plastic film 1 mil in thickness or the abrasive glass laminates in .500" plate, are machined with specimen configurations accurate to ± .0005". Machined edges are completely free of cold working or heat distortion and require no hand finishing.

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● TENSILGRIND is mounted on a metal cabinet and includes a totally enclosed ½ HP motor, micrometer adjustments, built in radial diamond wheel dresser, and solenoid controlled misting system to insure cool grinding of test specimen edges.

Write for descriptive literature.

SIEBURG INDUSTRIES INCORPORATED
Danbury Industrial Park, Danbury, Connecticut

Circle 37 on Page 48-B

• METAL
• PROGRESS
• BULLETIN
• BOARD

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The features listed below are but a few of the in-built advantages of the **LUCIFER 2055 SERIES.**

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- Rapid constant heat
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- Heat ranges to 1,700° F.
- All controls included (automatic indicating controller, selector switch with two thermocouples)
- Quick easy installation
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Lucifer Furnaces, Inc., manufacturers many standard electric heat treating furnaces and maintains a design department to create special units. For engineering assistance, parts or product information write or call . . .

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Neshaminy 7, Pennsylvania
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BY LUCIFER FURNACES

Circle 38 on Page 48-B

product defects

getting you down?

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✓ ***find hidden cracks***
with magnetic particle or dye penetrant inspection equipment

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Circle 39 on Page 48-B

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Circle 40 on Page 48-B

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Circle 41 on Page 48-B

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Literature
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Circle 42 on Page 48-B

- **NON-DESTRUCTIVE INSPECTION SORTING**
- **DEMAGNETIZING**

with
MAGNETIC ANALYSIS...

MULTI-METHOD EQUIPMENT

Electronic equipment for production testing of steel bars, wire rod, and tubing. Detects surface and sub-surface flaws and variations in composition and physical properties at speeds of 120 ft. per minute.

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Eddy current equipment for testing non-magnetic metal tubing, bars and wire, ⅛" to 3" in diameter, for surface and sub-surface flaws, at speeds from 200 to 600 ft. per minute. Multi-Frequency unit offers 6 simultaneous inspection methods, including 2 for indicating variations in mechanical, physical and metallurgical properties. Single Frequency unit offers 1 inspection method, and when used with D.C. energization, tests both magnetic and non-magnetic materials.

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COMPARATORS AND METAL TESTERS

Electronic instruments for production sorting of ferrous and non-ferrous materials and parts for variations in composition and structure.

DEMAGNETIZERS

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Circle 43 on Page 48-B

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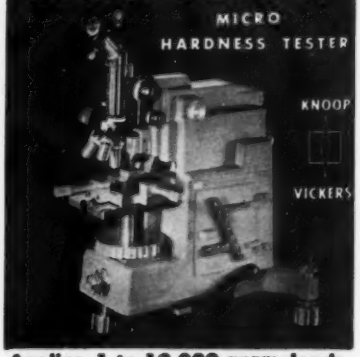

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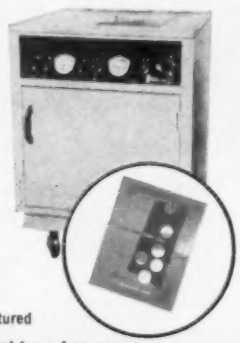
New

ROLL-AROUND ULTRASONIC CLEANERS



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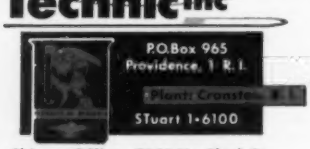

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Circle 54 on Page 48-B

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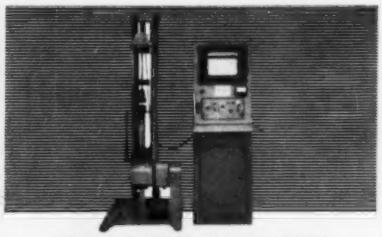

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Circle 57 on Page 48-B

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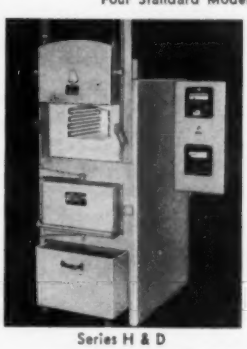

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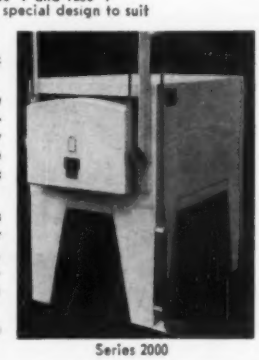

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Circle 60 on Page 48-B

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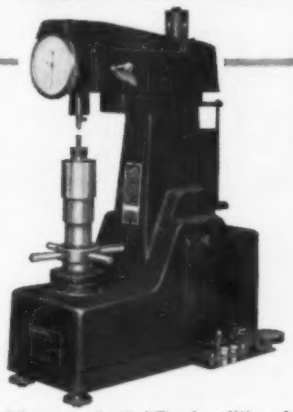

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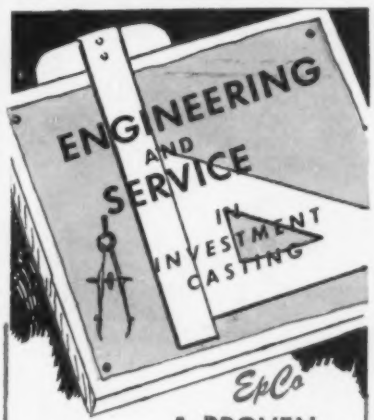

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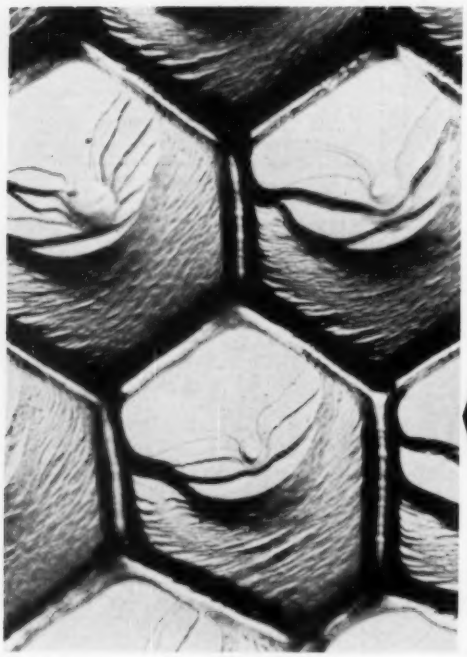

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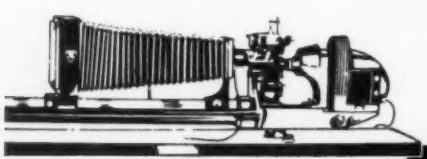

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Strengthening A.I.S.I. 4340

Digest of "The Effect of Prestraining and Retempering on A.I.S.I. 4340", by E. T. Stephenson and Morris Cohen, Preprint No. 248. Paper to be presented at the National Metal Congress, October 1961, Detroit.

THIS WORK WAS PERFORMED as an attempt to improve the strength of A.I.S.I. 4340 steel by a combination of thermal-mechanical treatments comprising hardening, tempering (400 to 1200° F.), straining (0 to 3%), and retempering (70 to 1200° F.) before testing. It shows that the combination of straining and retempering significantly raises tensile strength and yield-tensile ratio (the latter often to unity) and decreases tensile ductility, and that an optimum prestrain-tempering combination exists.

Bars of A.I.S.I. 4340, 0.5 in. in diameter, were normalized at 1600° F., stress relieved at 1200° F., air cooled, and machined into tensile specimens which were austenitized at 1525° F. and oil quenched. These hardened specimens were then pretempered for 1 hr., water quenched, prestrained in tension, retempered for 1 hr. and again water quenched.

The tensile properties investigated are yield stress, tensile strength, fracture stress, reduction of area, total elongation and "stable" elongation, the latter term being defined as the (plastic) elongation to the maximum load exclusive of prestrain. Yield stress was considered to be the stress at the upper yield point or the stress at 0.2% offset if there was no yield point. Yield stress, tensile strength, reduction of area, and total elongation were calculated from the *original* area and *original* length to reflect metallurgical differences relative to the unprestrained steel.

Specimens pretempered at 400° F., prestrained 3% and retempered at 400° F. give the greatest tensile and yield strengths. In unprestrained specimens, tensile properties usually were unaffected by retempering at or below the pretempering temperature. However, when the bars were prestrained, retempering increased the strength and decreased the ductility. Furthermore,

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PRODUCERS OF *MicroRold®* STAINLESS SHEET & STRIP

WASHINGTON, PA.

Circle 1568 on Page 48-B

A.I.S.I. 4340 . . .

retempering *above* the pretempering temperature appeared to wipe out the effect of prestraining. Similar results were observed for A.I.S.I. 4325 steel.

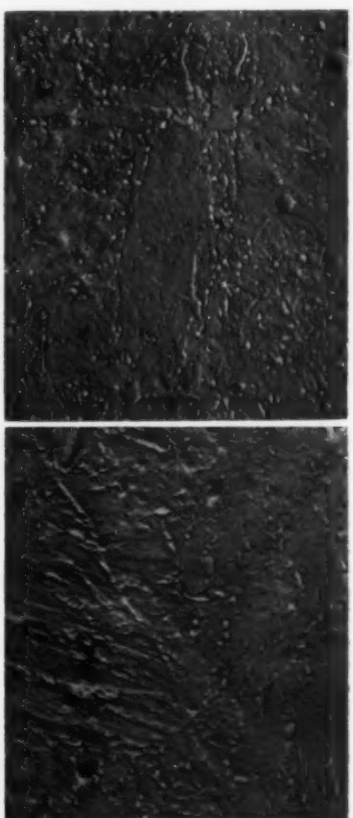
The strengthening produced by prestraining and retempering was accompanied by discontinuous yielding in the stress-strain curve to produce an upper and a lower yield point, as in alpha iron, with the maximum load occurring at the upper yield point. As the retempering temperature was raised above 400° F., the prestrain influence diminished, but similar trends were noted after retempering at 1000° F.

An analysis of the load-elongation curves showed that necking may have occurred later than the maximum load (which is indicated by the upper yield point) in the prestrained specimens. Thus, although uniform elongation continued to the onset of necking, it became unstable at the maximum load. After the upper yield point was reached, the steel stretched plastically to fracture under decreasing loads. Consequently, the strengthening by prestraining and retempering is probably of limited usefulness and may even be dangerous, because it may be accompanied by an almost complete loss of stable elongation.

Prestraining usually decreased notch-impact toughness. For the 400° F. pretemper and retempering at or below 600° F., an increase in prestrain from 0 to 3% caused the Izod notch-impact energy to decrease from about 15 to 10 ft-lb. At the higher pretempering or retempering temperatures, such as 800° F., prestraining had little effect on notch-impact value.

Electron micrographs showed the expected gradual coalescence of carbides in the unstrained material as

Fig. 1 — Prestraining of Heat Treated A.I.S.I. 4340 Appears to Introduce Dislocation Sites for Precipitation of Carbides During Retempering. Top, tempered at 600° F.; bottom prestrained 3% and retempered at 600° F.



Two new "Flinn & Dreffein Designed" 5-zone reheat furnaces made news recently when they were placed in operation at the new structural mill of United States Steel Corporation's South Works plant at Chicago.

The demand for larger sections, tonnage capacities and flexibility of heating operation dictated this advanced design.

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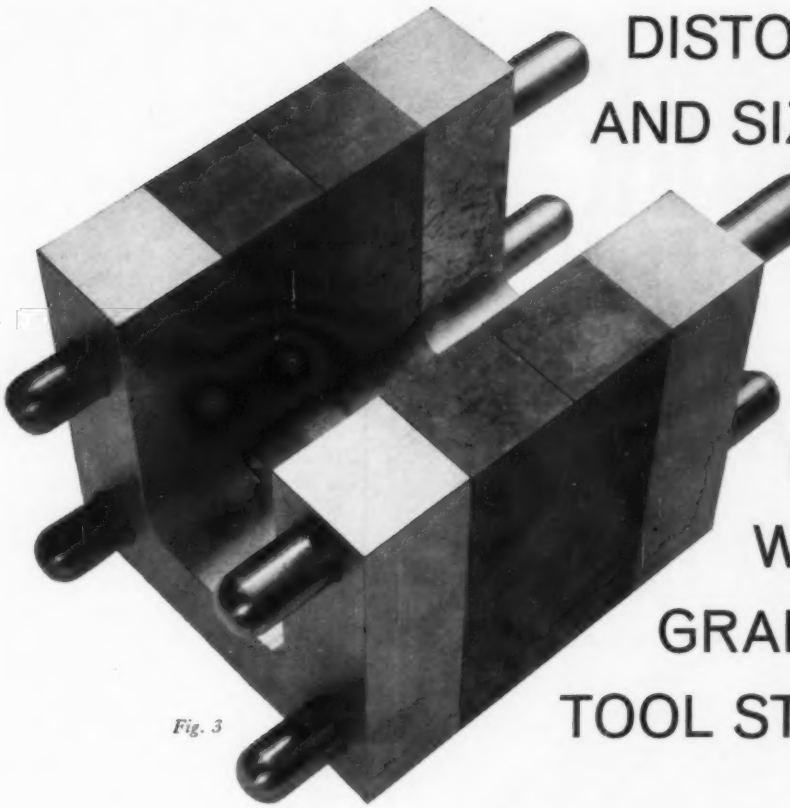
Circle 1569 on Page 48-B



DISTORTION AND SIZE CHANGE HELD TO LESS THAN .0002" PER INCH WITH GRAPH-AIR® TOOL STEEL

Fig. 3

The test pieces pictured here demonstrate the dimensional stability of Graph-Air® tool steel that enables users to produce more intricate tools and dies.

Fig. 1 shows test piece dimensions. In the "U" shape, which is particularly sensitive to distortion in heat treating, the machining tolerance between any two holes is held to .0002". After heat treating, the specimens are fitted together by four pins having a diameter of .0003" under .500". The total assembly error under these circumstances could not exceed .0008". Distortion must be less than .0002" per inch during heat treatment for the pins to fit.

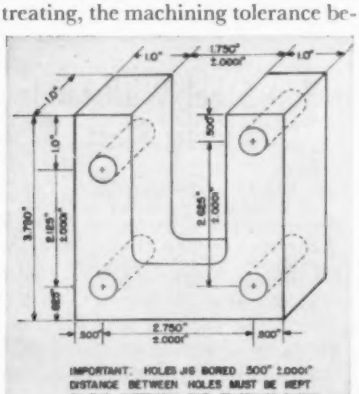


Fig. 1

The Graph-Air pieces tested were from different heats. They were air hardened from 1450°F. and double tempered at 400°F. Fig. 2 shows them as they pegged together easily, demonstrating no distortion. Fig. 3 top, shows the same specimens compared with two green, or as machined, parts. They matched perfectly again. *Graph-Air did not distort . . . did not change size.* Records indicate that no other tool steel passed this test when heat treated at its recommended hardening and tempering conditions.

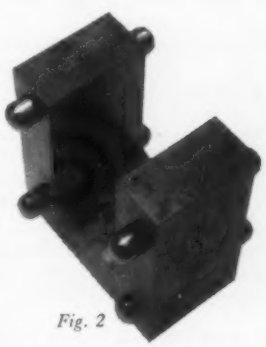


Fig. 2

Specify Graph-Air where minimum distortion and high quality are required. Solid and hollow bar sizes available. It is one of the Timken graphitic tool steels, the most stable tool steels made. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO". Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits.

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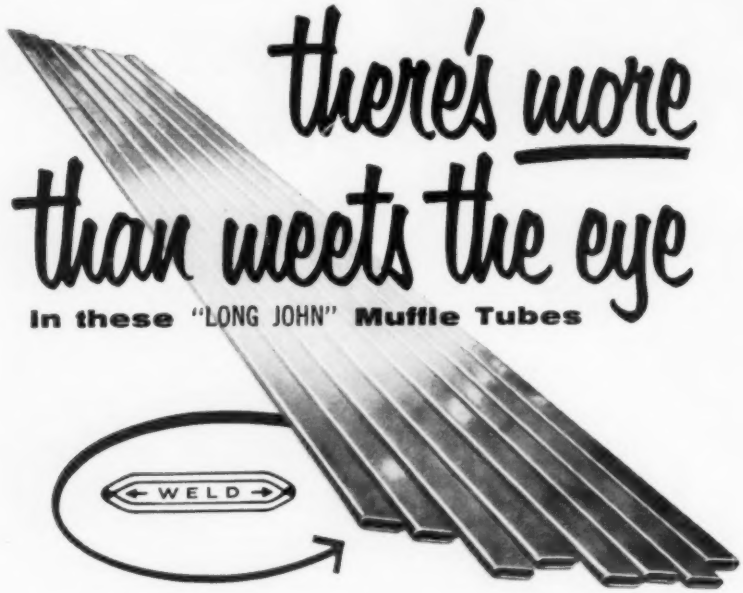

Even Rolock's welded-fabrication experts consider these 32-foot Inconel muffle tubes an exacting test of skill. The inset sketch shows how they are made, and the dimensions . . . 32 feet long by only 5½ inches O.A. width and 1 inch inside height . . . leave little room for any inaccuracy. These muffles . . . used for continuous bright annealing of steel strip . . . just *have* to be straight and true when installed, and stay that way in service.

We produce these muffle tubes "by the dozen" for use by the steel strip mills in gas-fired furnaces. Upper and lower sections are assembled separately with diagonal joints welded inside and out. The full length sections are then edge-welded together. Tight specifications call for no weld-splatter on the inside, and each tube is high vacuum tested to assure gas tightness. This is another example of Rolock service to key industries in building and designing many forms of special equipment that modern production processes call for.

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9RL57

Circle 1571 on Page 48-B

A.I.S.I. 4340 . . .

the retempering temperature was raised. Prestraining, however, led to important differences, as Fig. 1 shows. Apparently the operation introduced a higher density of dislocations which provided a finer distribution of stable sites for the carbon. (This new dispersion of carbides noticeably delineates the martensite plates.) Though the precipitated carbides were much finer than those in the as-pretempered or as-prestrained specimens, they coalesced in a somewhat elongated form as retempering was raised above 400° F. After retempering at 800° F. or above, little difference in carbide morphology remained with or without prestraining. It is suggested that this refinement of the carbides, achieved through their solution and reprecipitation, could readily account for at least part of the observed strengthening and loss in ductility.

Finally, a word about the possible relationship between the observed yield-point phenomenon and dislocation. The marked increase in yield point on retempering after prestraining suggests that the dislocations, generated or released by the deformation, become strongly pinned during retempering by the redistribution of carbides. In fact, this process appears to be so potent that the yield point coincides with the maximum load that the specimen can sustain. When this occurs, the yield-tensile ratio becomes unity and the stabile elongation approaches zero. O. O. MILLER

Rail Steel Withstands Atomic Blast

Digest of "Comparison Test of Reinforcing Steels", by R. H. Carlson and J. P. Murtha, U. S. Atomic Energy Commission's category "Health and Safety", publication WT-1473, Sept. 27, 1960.

IN A 1950 GOVERNMENTAL PUBLICATION on "The Effects of Atomic Weapons" it was stated that concrete reinforced with structural or "intermediate" grade steel bars is preferable to that with "hard-grade" steel, because "the softer steel may elongate or deform without failure

where the hard-grade steel snaps". A comprehensive literature search by the Rail Steel Bar Assoc. failed to show any documentary evidence of this sort. In fact the statement is contrary to experience: When concrete structures, reinforced with bars re-rolled from scrap railroad rails, are demolished by dynamiting, the concrete is shattered but the bars do not break.

This point was investigated by the U. S. Atomic Energy Commission in one of the nuclear explosions in 1957 at the Nevada Test Site. Two cellars were roofed (at ground level) with 9 × 24-in. slabs of 19-ft. span. One cellar was 4200 ft. from the explosion and received a blast of 7 psi. peak pressure; the other was 5200 ft. away and was hit by a 5-psi. blast.

The roof beams under test were in identical pairs, reinforced top and bottom with ⅝-in. deformed bars, except that the steel in one beam of each pair was deformed rail-steel bars conforming to A.S.T.M. specification A 16-54 T and the other contained "intermediate grade" steel bars (A.S.T.M. A 15-54 T; Billet-Steel Bars for Concrete Reinforcement). The strongest pair was designed according to the American Concrete Institute's building code to resist a static yield load of 34,000 lb. Weaker pairs then contained less and less reinforcing steel. The weakest pair should have withstood a static load of 12,000 lb. without yielding.

The specification for rail-steel bars for concrete reinforcement calls for tensile strength of 80,000 psi. min., yield point of 50,000 psi. min. and elongation of 12.5% min. The A.S.T.M. specification for rails permits a carbon content of 0.60 to 0.75%, varying with the weight of the section, and also calls for low phosphorus; no tensile properties are required, main reliance being on the rail's resistance to a falling 1-ton tup.

The specification for billet-steel bars for concrete reinforcement, deformed bars, intermediate grade, calls for tensile strength of 70,000 to 90,000 psi., yield point of 40,000 psi. min., and elongation of 12% min. in 8 in. The only chemical composition calls for relatively high phosphorus – up to 0.12% in rephosphorized heats.

Tensile tests on the actual bars

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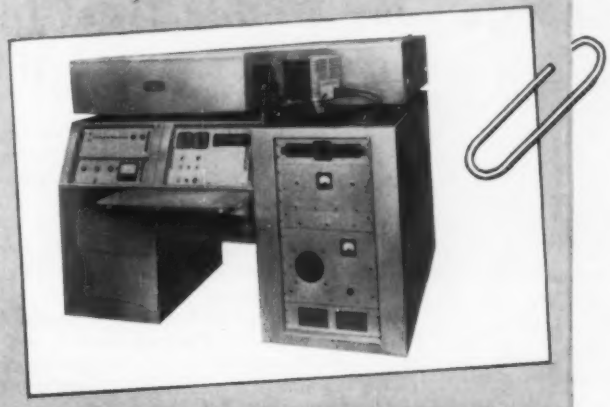

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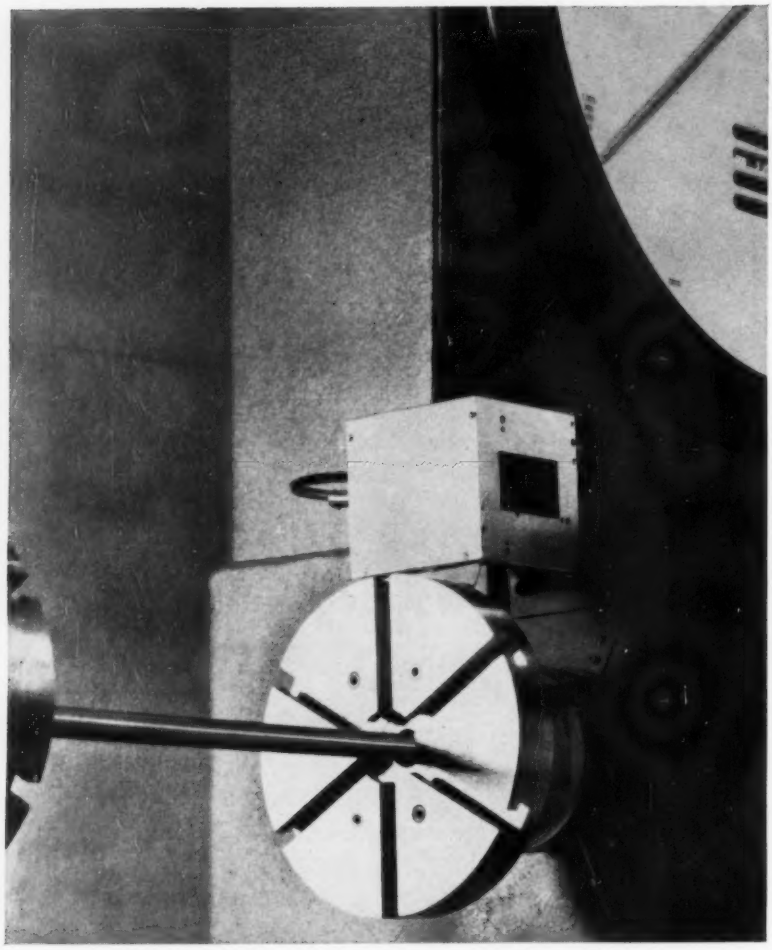

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Circle 1573 on Page 48-B

Rail Steel . . .

used in this investigation gave, on the average:

	Rail Steel	Intermediate Grade
Ultimate	120,000	77,000
Yield	77,000	50,000
Elongation in 2 in.	12 to 24%	24 to 36%

After the blast, it was found that all beams were permanently bent downward into the cellar. None collapsed. The least permanent deflection was 1.7 in. at the center of the strongest beam reinforced with rail steel. The greatest permanent deflection was 25 in. in the weakest beam reinforced with intermediate grade. The beams reinforced with intermediate grade were deformed much more than their counterparts reinforced with rail steel; the average was 2.4 times. The maximum permanent stretch in the rail steel bars after the test was 2% in 10 in.; there were no tensile failures.

The authors conclude: "Within the limits of the experiment, no evidence of brittle failure of rail steel was observed."

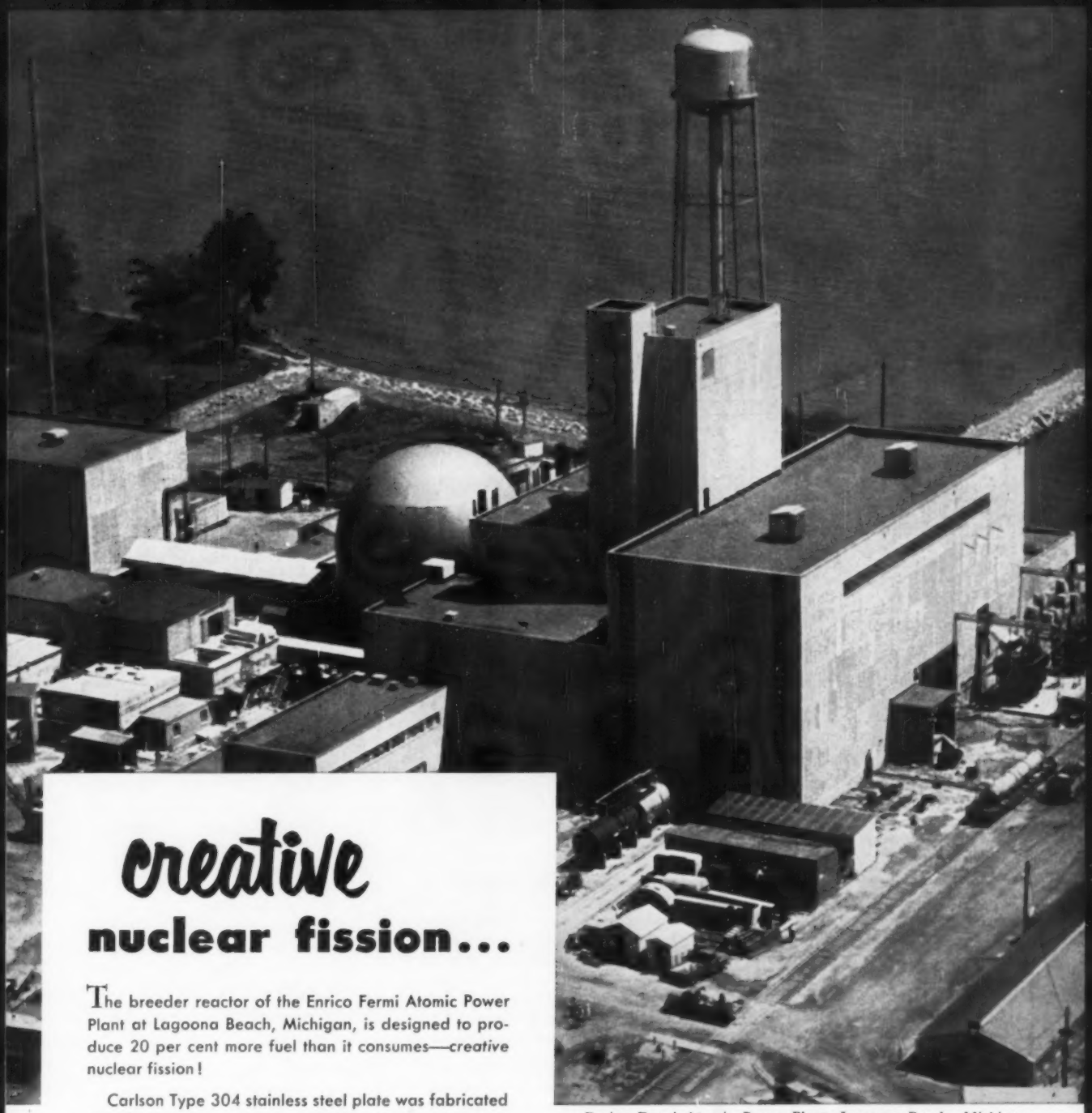
E.E.T.

Short-Time Rapid-Heating Tests

Digest of "Methods for Conducting Short-Time Tensile, Creep, and Creep-Rupture Tests Under Conditions of Rapid Heating", by D. P. Moon and W. F. Simmons, DMIC Report 121, Battelle Memorial Institute, Dec. 28, 1959. 38 p.

SHORT-TIME, HIGH-TEMPERATURE requirements for supersonic aircraft and missiles are beyond the range of existing conventional data nor can they be obtained by extrapolation of the latter. This deficiency has led to development of new tests of relatively short duration with rapid heating of test specimens, either under load or followed by rapid application of load.

The American Society for Testing Materials has issued two "Recommended Practices" for tensile and creep testing after rapid heating based on practices proved by competent investigators. However, these "Recommended Practices" do



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Circle 1574 on Page 48-B

Short-Time Tests . . .

not cover load application during rapid heating. The wide variety of current test practices suggests further standardization in both areas.

Testing machines currently in use may be dead-weight loading, screw-driven (with controlled strain rates between 0.00005 and 1 in. per in. per sec.), or hydraulic-driven.

Test specimens should be representative of the material, and the A.S.T.M. recommends a gage length of four times the diameter (or width) in wire, sheet, plate, or strip specimens. Form and dimensions of specimen ends depend on the temperature control method as well as the loading and strain-measuring devices. Reasonable temperature uniformity is desired over the gage length. It can be accomplished by making the reduced section much longer than the gage length, adding extra heat at the specimen ends, or cooling the center of the specimen.

The A.S.T.M. recommends heating to nominal test temperature in 30 ± 5 sec., a maximum overshoot of not over 2% for not over 5 sec., and a maximum variation in temperature no greater than ± 1% thereafter for heating followed by load application. Under these circumstances a high-power supply is almost mandatory for rapid heating as is a low-power supply for maintaining temperature. For rapid-heating constant-load tests, a reasonably constant heating rate is desired. Four heating methods (or combinations thereof) are satisfactory. These are: (*a*) resistance of the specimen to passage of an electric current, (*b*) high-frequency induction heating, (*c*) radiant-heating, and (*d*) hot-fluid heating to simulate aerodynamic heating.

Accurate temperature measurement is difficult since the instrument must have a response which is both accurate and instantaneous. Most temperature measuring methods use thermocouples with minimum size wire to reduce lag in response and minimize cooling the specimen at the contact point. A correction may be required to convert indicated temperature to "true" temperature. Radiation pyrometers are also used.

Accurate load measurement is simple with dead-weight loading. For loading at moderate strain rates after rapid heating, sufficient accuracy can usually be obtained by using the load dial or an autographic stress-strain recorder. In any event, however, the response of the indicator must be faster than the rate of load increase. Thus, for accurate load measurement with very rapid heating or strain rates, calibrated dynamometers are normally used.

For accurate strain measurement, the extensometer must either be kept at its original temperature, or be designed to be unaffected by the heating. It should also exert negligible strain on the specimen and have a more rapid response than the imposed strain rate. Its indication must be capable of being recorded by high-speed techniques.

Time, temperature, load, and strain must be continuously recorded during the test, and each instrument must be able to follow the rate of change of the variable being measured. Except for mechanical transfer of data through an autographic stress-strain recorder, data-measur-

4 NEW ROCKWELL ANNEALERS for Aluminum Coil Strip

Proof positive of Rockwell's all-around ability to do the complete job—large or small. Bulletin 128 gives more evidence—yours on request.

These high velocity, recirculating type ovens, recently installed at Bridgeport Brass' Warren, Ohio, plant, are used for atmosphere annealing coiled aluminum strip of many widths and gages. They constitute a new addition to the long list of outstanding Rockwell installations in the aluminum industry.

They are used to heat, soak and cool aluminum coils in an exothermic atmosphere with closely controlled temperature uniformity, despite a work load of up to 30,000 lbs. per batch.

Included in this Rockwell-engineered project are the cooling systems for the ovens, exothermic gas generators, temperature and safety controls, work trays, etc.

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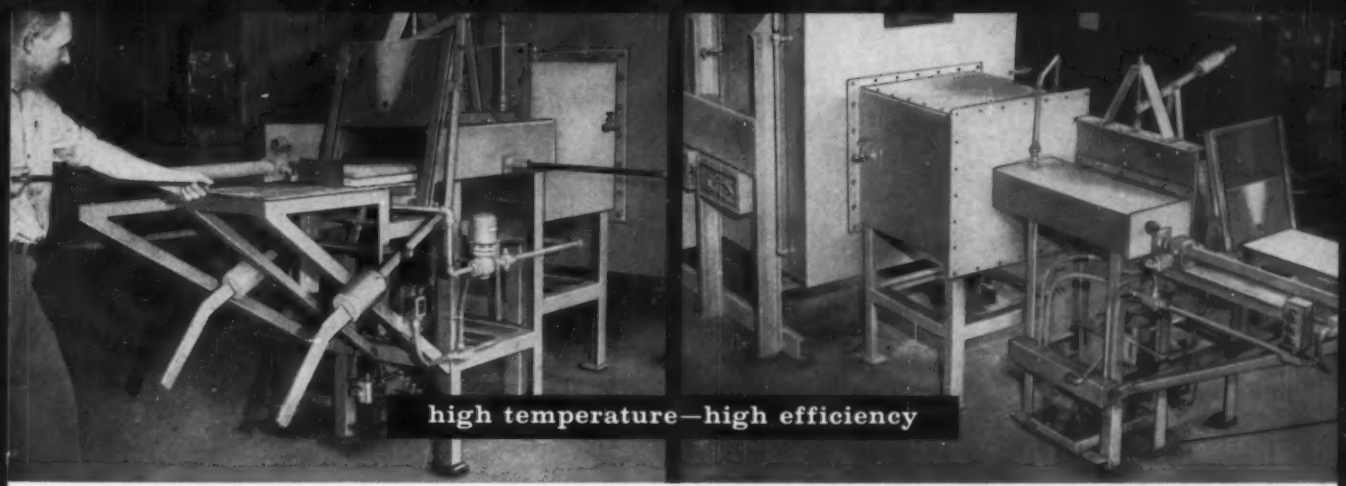
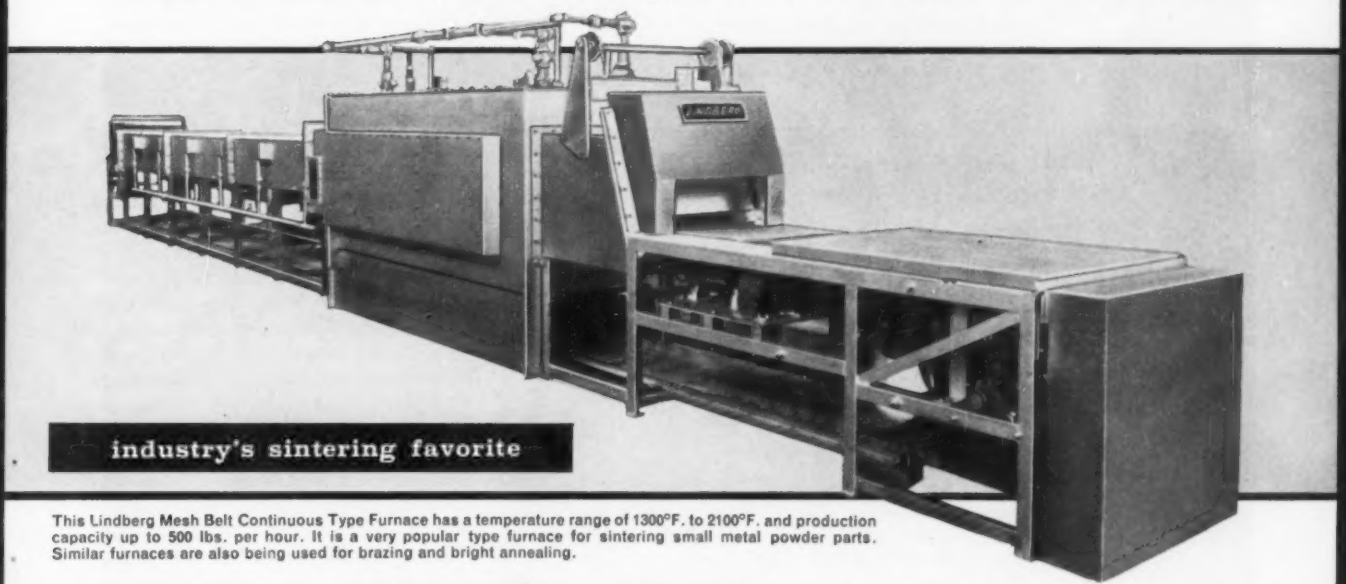
Circle 1575 on Page 48-B



This new Lindberg Molybdenum Element Pusher Type Atmosphere Furnace has a maximum temperature of 3000°F. with 60KW input. It embodies high temperature refractories suitable for low dew point without muffle and is ideal for sintering stainless steel compacts in hydrogen or dissociated ammonia. Furnace provides side loading and discharge ports with purging chambers. Installation at right also shows conveniently located ammonia dissociator and control panels.

If your production processes require sintering you can depend on getting exactly the right equipment for your needs from Lindberg's comprehensive line of dependable, efficient, production-proven furnaces



This Lindberg Mesh Belt Continuous Type Furnace has a temperature range of 1300°F. to 2100°F. and production capacity up to 500 lbs. per hour. It is a very popular type furnace for sintering small metal powder parts. Similar furnaces are also being used for brazing and bright annealing.

Lindberg Roller Hearth Continuous Type Furnace handles loads up to 2200 lbs. per hour in temperature range 1300°F. to 2100°F., for bright annealing, silver brazing and sintering metal powder.

Lindberg Hand Pusher Batch Type Furnace has a temperature range of 1300°F. to 2500°F. Also sintering capacities from 25 to 300 lbs. per hour available.

For full information on the furnaces illustrated and Lindberg's complete line of sintering and brazing furnaces, just get in touch with your local Lindberg Field Representative (see classified phone book) or write direct. Please remember, too, that Lindberg offers a variety of Atmosphere Generators to provide, efficiently and economically, the proper atmospheres recommended for use with our sintering furnaces. Heat Treating Furnace Division, Lindberg Engineering Company, 2448 West Hubbard Street, Chicago 12, Illinois.

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Circle 1576 on Page 48-B

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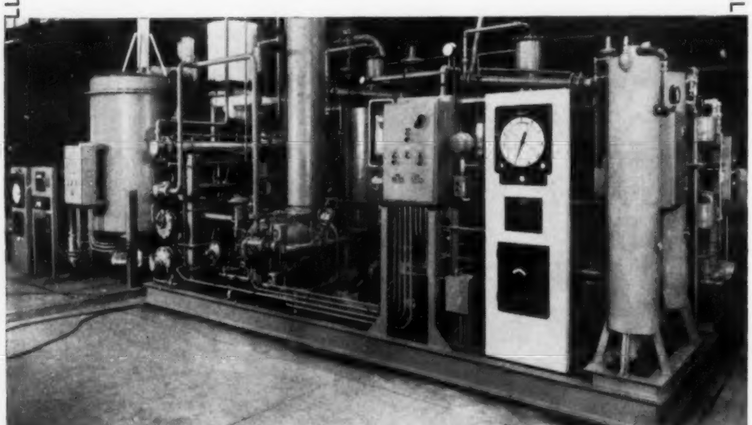

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GAS ALLOYING GAS ALLOYING GAS ALLOYING

Circle 1577 on Page 48-B

Short-Time Tests . . .

ing instruments generally depend on an electrical output (thermocouples and pyrometers) or modification of an electrical input (strain gages and linear transformers). Oscillographs and high-speed motion photography are often used. C. O. Smith

Extruding Toolsteel

Digest of "The Extrusion of High-Speed Steel Sections", by J. Sukolski and G. Hoyle, *Journal* of the Iron and Steel Institute, November 1959, p. 270-277.

The extrusion process is particularly attractive for converting steel ingots when the batch sizes are small, where rapid changes are required from one section to another, where sections cannot be produced by rolling and where materials are difficult to hot work. High speed steels are often forged as well as rolled, in combination with several reheats. Finally, the bars are machined to final dimensions. It appeared that extrusion could replace the above sequence of operations, the final shape being obtained in one operation. The work carried out by the authors was done on an 18-4-1 high speed steel. The as-cast structure of this steel contains a large proportion of eutectic as grain-boundary envelopes and individual colonies. To produce tool metal from this structure, it is considered necessary to eliminate all traces of cellular structure by hot working to a reduction of 90 to 95%.

The extrusion experiments were carried out on a 400-ton horizontal, dead-weight accumulator, hydraulic press. The container had a 2¾-in. diameter bore, which accommodated slugs 2⅝-in. diameter by 4 to 5 in. long. The lengths of the extruded bars varied from 2½ to 20 ft. For lubrication an agglomerated glass-powder pad was placed between the die and billet while the hot billet itself was rolled in glass powder before being inserted into the container. The press was operated on a ram speed of about 2 in. per sec. All of the slugs were preheated to 300° C. (570° F.) and transferred directly into the hot furnace which was sometimes as high as 1310° C. (2400° F.).

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Extruding Toolsteel . . .

Ranges of size of the extruded bars included 1 in., ¾ in., ½ in., and ⅜ in. diameter (extrusion ratios of 7.6, 13.3, 30.2 and 53.8, respectively) produced from as-cast and heat treated slugs. Despite the porosity and generally poor quality of many of the slugs, all of the bars extruded satisfactorily at between 1150 and 1280° C. (2100 and 2340° F.). There was no appreciable difference between bars extruded between 1200 and 1280° C. (2190 and 2340° F.), but at 1150° C. (2100° F.) there was some tendency to streakiness in the direction of the bar. Extrusion ratio had no effect on surface finish. Bars extruded at 1300° C. (2370° F.) showed an extensive area of circumferential cracks. Bars extruded at 1300° C. (2370° F.) showed an extensive area of circumferential cracks. Bars from pretreated slugs were worse than as-cast ones.

Metallographic examination of extruded as-cast bars showed that the homogeneity is improved by increasing the reduction. To insure freedom from the eutectic phase, it was necessary to extrude to ¾ in. diameter or smaller bars. Little change in macrostructure was found when the temperature was varied between 1150 and 1280° C. (2100 and 2340° F.). Increasing heating time reduced the severity of carbide stringers. Optimum extrusion temperature for 18-4-1 steel was 1280° C. (2340° F.). A 30-min. soak may give a superior structure.

During the experiments, particular attention was paid to the behavior during extrusion of internal cavities in these slugs. Exposed central cavities will oxidize. In general, however, samples were free from oxidized cavities and porosity which indicated that any blowhole present had been completely healed during the extrusion process.

To control the rate of cooling of the extruded bar, each bar was extruded into a trough of vermiculite. In most situations, the hardness levels of the bars were shown to be acceptable for most applications, indicating that a sample of satisfactory hardness and structure can be obtained in 18-4-1 high speed steel by hot extrusion, cooling and double tempering without intermediate annealing and heating for hardening.

Bend tests carried out on extruded and conventionally produced bars showed that their properties were very similar. Drilling tests were also carried out by comparing two extruded and two conventionally produced drills in the British Standard drilling test. The results suggest superiority of the extruded samples over the forged and rolled material.

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Circle 1579 on Page 48-B

Effects of Centrifugal Casting

Digest of "Hydrodynamic Condition of Metal in Centrifugal Casting and Effect on Macrostructure", by N. N. Reutov, *Liteinoe Proizvodstvo*, Vol. 10, No. 6, 1959, p. 22-27; Brutcher Translation No. 4771.

IN THE PRODUCTION OF centrifugal castings, it has long been thought that the soundness of the casting and its crystal structure are generally de-

termined by the rotational speed (rpm.) of the mold. In contradiction, this paper reports upon a number of experiments which indicate that the hydrodynamic condition of the metal is a major influence, and that the rpm. is only one of several important factors.

Experiments were conducted in a mold (about 10 in. long and 8 in. in diameter) rotating at speeds from 0 to 1600 rpm. Materials studied included water, wood, metal, zinc, and chromium-nickel steels. Variables included the speed of rotation of the mold, viscosity of the liquids being cast, and the pouring rates.

Results of these experiments indicated that the quality of the finished casting is strongly dependent upon keeping a static liquid bed in the mold. Below a critical rpm. for any set of conditions, the metal rotates more slowly than the mold. This at first is lamellar flow, then turbulent flow, and finally break-away, as the speed is reduced. The critical speed is a function of casting diameter, thickness, viscosity and rate of pour into the mold. It was also observed that, after pouring was complete, static liquid beds could be maintained at lower critical speeds.

Microstructures of the castings were found to vary with pouring temperature, the columnar crystal zone decreasing in thickness with decreasing temperature. This is predictable on the basis of time required to establish steady-state conditions (or radial thermal gradients) during pouring.

Various crystal structures were developed by the author by varying rotational speeds, by reversing the rotational direction during solidification, and by careful temperature control. Typical structures and techniques for their development are included in the paper. J. L. WYATT

Brazing Parts for High-Temperature Service

Digest of "High-Temperature Brazing With Palladium-Containing Filler Alloys", by E. R. Perry, *Australasian Engineer*, May 7, 1959, p. 53-56.

THE ADVANTAGES of brazing as a production process are discussed with particular reference to other joining processes. The process can be made automatic and subject to quality control. Parts with places inaccessible to other processes can be joined as can sheet 0.002 in. thick. Little or no final machining is necessary, and there is a very good resistance to corrosion. New alloys with useful properties at high tem-

Table I – Palladium-Containing Brazing Alloys

COMPOSITION	MELTING RANGE	BRAZING TEMPERATURE
68.4% Ag, 26.6% Cu, 5.0% Pd	1485 to 1490° F.	1500° F.
95.0% Ag, 5.0% Pd	1780 to 1850	1860
75.0% Ag, 20.0% Pd, 5.0% Mn	1830 to 2050	2048
60.0% Pd, 40.0% Ni	2260	2280

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An experimental installation for removal of residual smudge from shot blasted strip by means of ultrasonics. A joint project of Pangborn Corp., Wean Engineering Co., Inc., and Branson Instruments, Inc.

The shotblast method of descaling strip is becoming more and more popular, especially among the lower tonnage producers, converters and fabricators. In this process, hot bands are descaled in a blast cabinet with abrasive shot.-Today ultrasonic cleaning is on the way to replacing flash pickling. This method, which eliminates stream pollution and acid disposal, offers many extras:

• LOW INITIAL INVESTMENT (for tanks due to inexpensive steel construction) • LOW MAINTENANCE COSTS • LOW OPERATING COSTS (in terms of heat and power input) • REDUCED OPERATING TEMPERATURES • LITTLE OR NO CORROSION • NO FUME REMOVAL • NO ACID DISPOSAL • SPACE SAVING (ultrasonic installations are shorter in length).

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Brazing . . .

perature have been developed, and the application to parts for gas turbines and radio tubes are mentioned. The traditional silver solder is given improved strength properties at high temperatures by the addition of palladium, and this metal is also alloyed with nickel to produce new alloys.

A range of eleven alloys is quoted with brazing temperatures ranging from 1500° F. (815° C.) to 2280° F. (1250° C.). The strength of the alloys is not mentioned, but an example is quoted of a Nimonic 90 alloy brazed at 1470° F. (800° C.) which has a stress-rupture life of more than 1000 hr. at 4500 psi. Typical alloys are listed in Table I.

Advantages claimed for these alloys include excellent wetting properties; a safety factor when working temperatures are exceeded; step-by-step brazing of complicated components (because of the wide range of brazing temperatures of different alloys); freedom from intercrystalline brittleness when used with low expansion alloys. These alloys, have been successfully applied to cobalt-base alloys, gold, molybdenum and tungsten. JOSIAH JONES

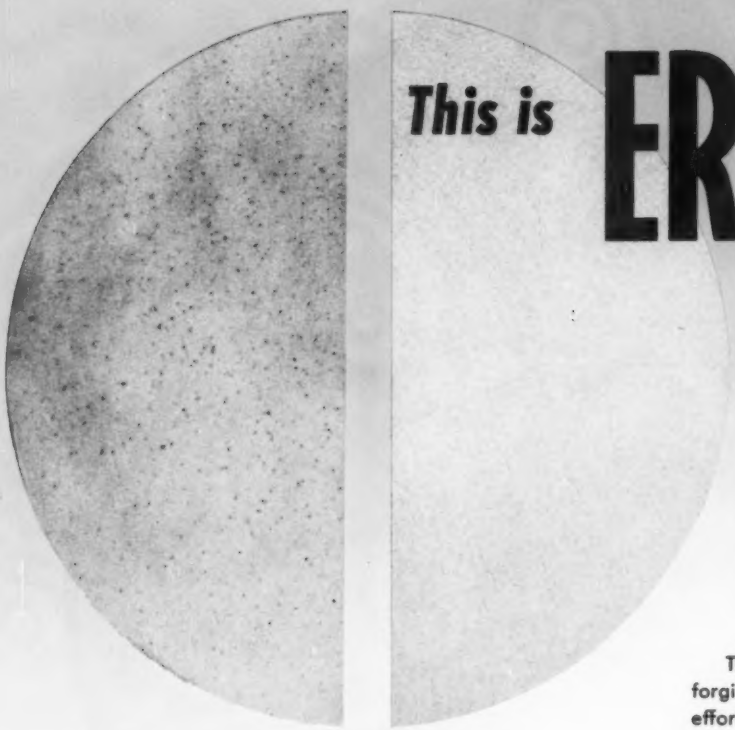
Corrosion in Reactors

Digest of "Corrosion Problems in Gas-Cooled Nuclear Reactors", by A. Draycott, *Chemical Processing*, December 1959, p. 21-27.

THE AUTHOR, a senior research officer of the Australian Atomic Energy Commission, describes corrosion problems resulting from gases, particularly carbon dioxide, used for cooling thermal nuclear reactors. Such gases may corrode any of four specific components of nuclear reactors: (*a*) the moderator, such as graphite, beryllium or beryllia, light or heavy water; (*b*) the canning material which holds the fuel, such as aluminum, magnesium or its alloys, beryllium, and stainless steel; (*c*) the fuel in event of can failure, such as uranium metal, uranium oxide, uranium carbide, intermetallics as UBe_{13}, and thorium when used for breeding purposes; or (*d*) the structural material (some variety of steel for ductwork and heat exchanger). (*Cont'd on p.* 170)

This is ERIE-V-DOX

PATENT PENDING



VACUUM DEGASSED STEEL—SILICON DEOXIDIZED

Hot-acid etched, transverse section showing typical segregation pattern in silicon-deoxidized forgings.

ERIE-V-DOX STEEL—VACUUM DEOXIDIZED

Hot-acid etched, transverse section showing a minimum of segregation required in critically inspected forgings.

Vacuum Deoxidation A Major Advance In The Production of Cleaner Steel Forgings With A Minimum of Segregation

The production of cleaner, more nearly uniform steel forgings with minimum segregation has been a continuing effort at Erie Forge & Steel Corporation for many years. A significant advance was made in 1958 with the introduction of vacuum degassed, basic electric furnace steel.

Now, using this modern equipment, an even greater step forward has been achieved — the vacuum deoxidation of large steel ingots for forgings.

ERIE-V-DOX Minimizes Oxide Inclusions In Finished Forgings

In the time-tested method of deoxidizing steel, silicon is introduced into the melt. The silicon unites with dissolved oxygen to form oxide inclusions. In certain critically inspected forgings, the minimization of such inclusions has long been a prime objective of the steel industry.

In the ERIE-V-DOX process, silicon is **never** added to the steel. In the vacuum chamber, the carbon in the steel unites with the dissolved oxygen to form carbon monoxide which is vacuum-removed simultaneously with hydrogen and other gases. Thus two desirable ends are achieved: oxygen content is materially reduced and oxide inclusions are minimized.

For large or small forgings which require clean steel to comply with rigid requirements, the ERIE-V-DOX process produces steels with fewer inclusions and only small amounts of gas. In addition to generator and turbine rotors the ERIE-V-DOX process can be applied to a wide range of forgings and rolled products requiring cleaner steel. Consideration is being given to the use of vacuum deoxidized steel for consumable electrode remelting.

ERIE-V-DOX Process Passes Rigorous Tests

In September 1959, an experimental 37½ x 35,000 pound ingot of carbon steel was produced by the ERIE-V-DOX process. Ultrasonic testing of the forging, as well as hot-acid etched cross sectional slices from the top and bottom of the ingot, showed greatly improved cleanliness and soundness. Repeated tests on both carbon and alloy steels since that time have substantiated these findings. Ingots 64" x 155,000 pounds have been, and are being, produced by the ERIE-V-DOX Process.

The ERIE-V-DOX Process has been successfully applied to generator and turbine rotor forgings, as well as to several other types of critically-tested forgings. Outstanding results were produced. Examination of the center bore and ultrasonic inspection of the finished forgings fully satisfy the most critical specifications for such forgings.

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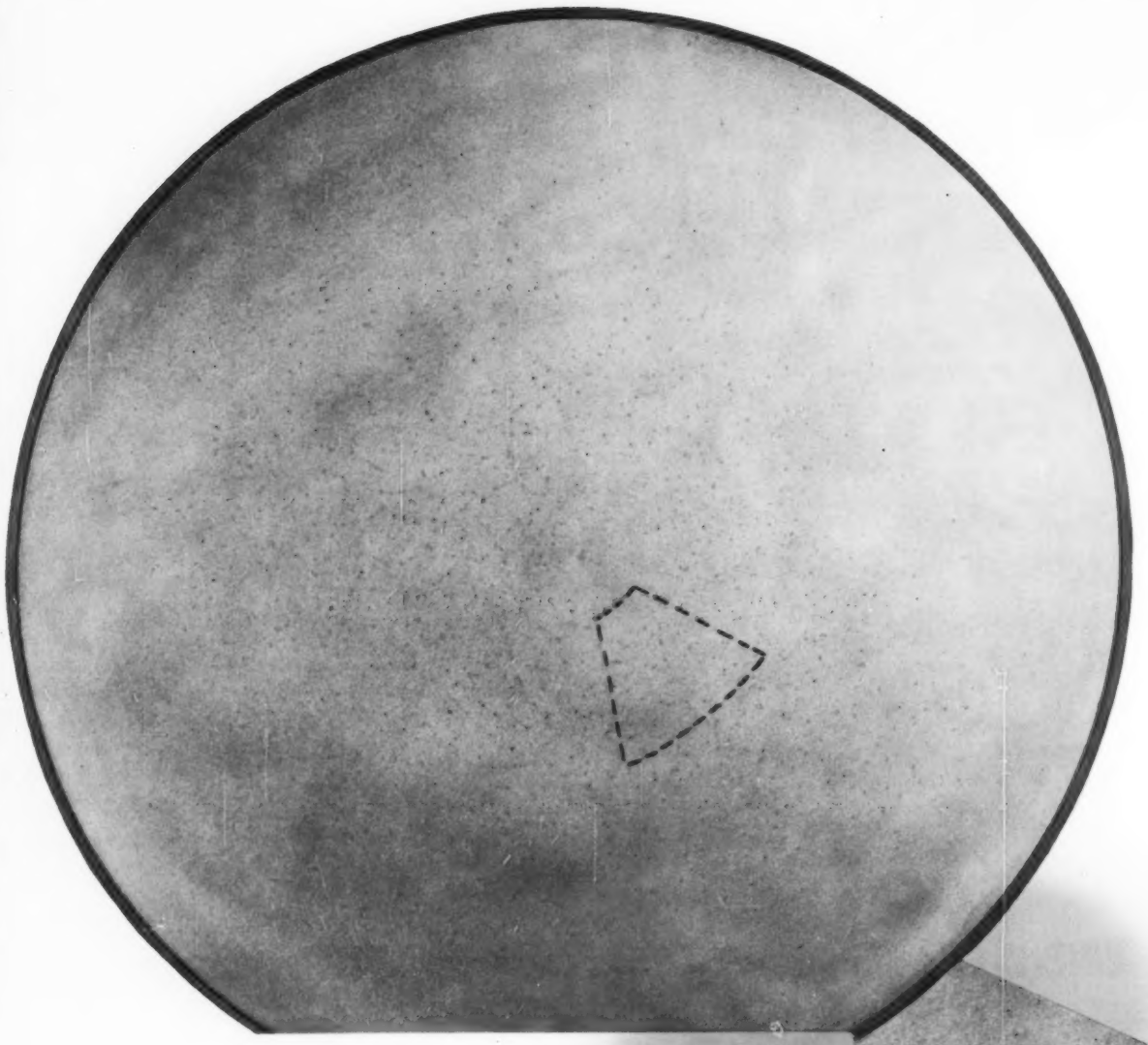

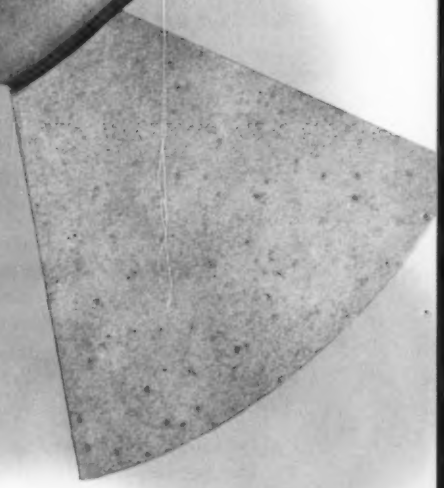

Vacuum Degassed Steel
Silicon Deoxidized

The unretouched photographs, above and right, show a typical segregation pattern after hot-acid etching of a transverse section from the top end of a forging prolongation. The steel in this forging (produced from a 64" diameter x 155,000 pound ingot) was fully deoxidized by the addition of silicon prior to vacuum degassing.

The above photograph has been reduced approximately 3 times. Photographic section at right is shown in full size.

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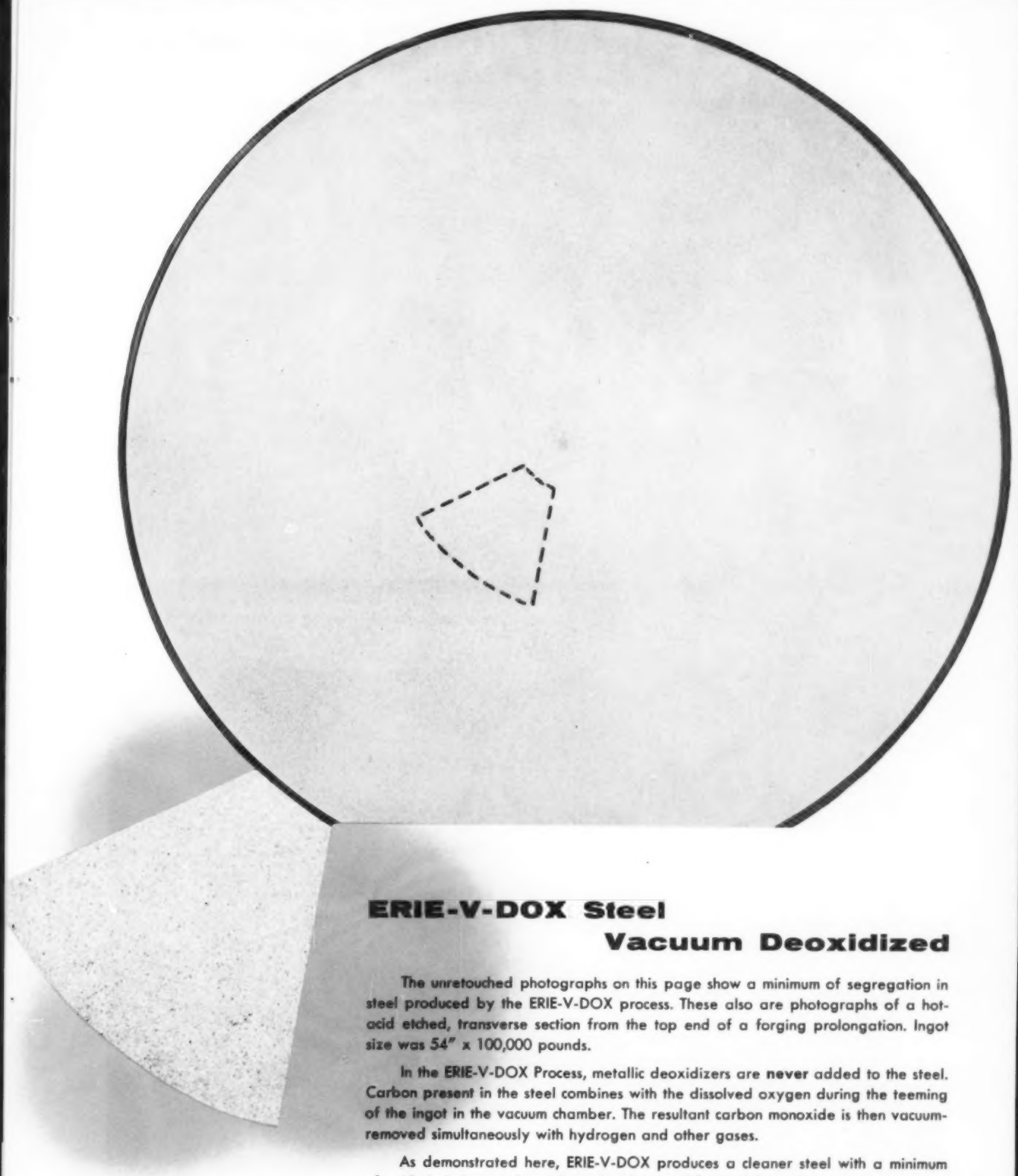


ERIE-V-DOX Steel
Vacuum Deoxidized

The unretouched photographs on this page show a minimum of segregation in steel produced by the ERIE-V-DOX process. These also are photographs of a hot-acid etched, transverse section from the top end of a forging prolongation. Ingot size was 54" x 100,000 pounds.

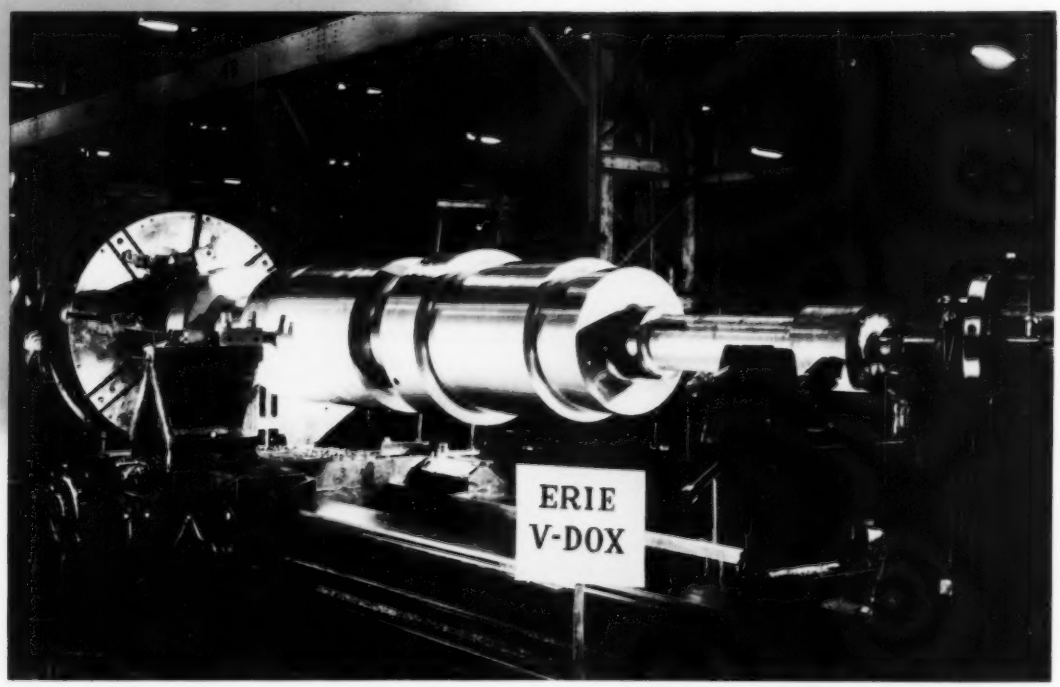
In the ERIE-V-DOX Process, metallic deoxidizers are **never** added to the steel. Carbon present in the steel combines with the dissolved oxygen during the teeming of the ingot in the vacuum chamber. The resultant carbon monoxide is then vacuum-removed simultaneously with hydrogen and other gases.

As demonstrated here, ERIE-V-DOX produces a cleaner steel with a minimum of oxide inclusions and a uniform distribution of fine sulfide inclusions. In addition, the total oxygen content has been materially reduced.

The above photograph has been reduced approximately 3 times. Photographic section at left is shown full size.

Shown Below – Typical *ERIE-V-DOX* Steel Forgings

A 10-THROW DIESEL ENGINE CRANKSHAFT DURING FINISH MACHINING



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Sunquench 1070 is particularly important in fast-quenching operations because it cools at the optimum rate during the critical stage, minimizes distortion, deepens hardness. With Sunquench 1070, you may be able to substitute lower alloy steels for more expensive grades. Exceptional thermal stability of Sunquench 1070 means long life.

3 Get Brighter Parts

Sun Quenching Oil 11 is a premium-quality paraffinic quenching oil designed for work requiring an oil with a high flash point. It is particularly good for bright quenching. Its high thermal stability prevents decomposition and the resultant streaks on bright-quenched parts.

4 Get Longer Marquench Oil Life

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Circle 1581 on Page 48-B

Corrosion . . .

Hydrogen, helium, carbon dioxide, nitrogen, air and argon are the common gases which have the best cooling properties. Of these, argon (because it forms the intense gamma ray emitter, isotope A^{41}, under irradiation) and hydrogen (because of its embrittling effect on steel structural material and its rapid diffusion through many materials) are not considered here. Carbon dioxide has heat removing properties approaching those of the more expensive and scarce helium. Air and nitrogen are at the bottom of the list for heat removing properties, and nitrogen yields C^{14}. These latter four gases are listed in the following order of priority; carbon dioxide, helium, nitrogen and air. This paper is limited to carbon dioxide compatibility problems, and only briefly describes corrosion problems from the other three gases.

Temperature, pressure, gas velocity, irradiation, initial form of the solid, surface finish, and gas impurity are the main factors which affect corrosion in reactor systems. Each of these variables was examined in the above systems by employing several types of tests.

The corrosion of graphite moderators by carbon dioxide is not a problem for reactors operating below 600° C. (1110° F.) since chemisorption of oxygen on the graphite is the only reaction. Above 600° C., carbon monoxide is produced by the reaction $CO_2 + C \rightarrow 2\,CO$, and graphite is removed. The reverse reaction of carbon deposition could then take place at the lower temperatures in the heat exchanger tubes and interfere with the heat transfer. It would be necessary to prevent this reaction by either coating the graphite or using another material. Beryllia or heavy water are alternates for the higher temperatures. Beryllia could be used up to 950° C. (1740° F.) if its stability under irradiation is proved and heavy water does not come into contact with the carbon dioxide.

Canning materials, in addition to having good corrosion resistance, should possess a number of desirable properties including a low-thermal neutron capture cross section. Magnesium alloys are limited to surface temperatures of about 500° C. (930° F.) in carbon dioxide cooled reactors since oxidation becomes excessive at high temperatures. A little beryllium or calcium added to the alloy improves its oxidation resistance. Beryllium is the favored canning material up to 625° C. (1160° F.) when the moisture content of the carbon dioxide is less than 50 ppm. Moisture in the carbon dioxide causes an increase in rate of oxidation (breakaway) after a given time at temperature. Zirconium exhibits poor oxidation resistance to carbon dioxide above 570° C. (1060° F.). Like beryllium, it also displays breakaway behavior, and is not used in carbon dioxide reactors above 500° C. (930° F.). Columbium displays poor corrosion resistance to CO_2 even at 500° C. Aluminum, because of its low melting point and incompatibility with metallic uranium at 400° C. (750° F.), is not considered. Stainless steels can be used up to 650° C. (1200° F.) in carbon dioxide containing <50 ppm moisture. Be-

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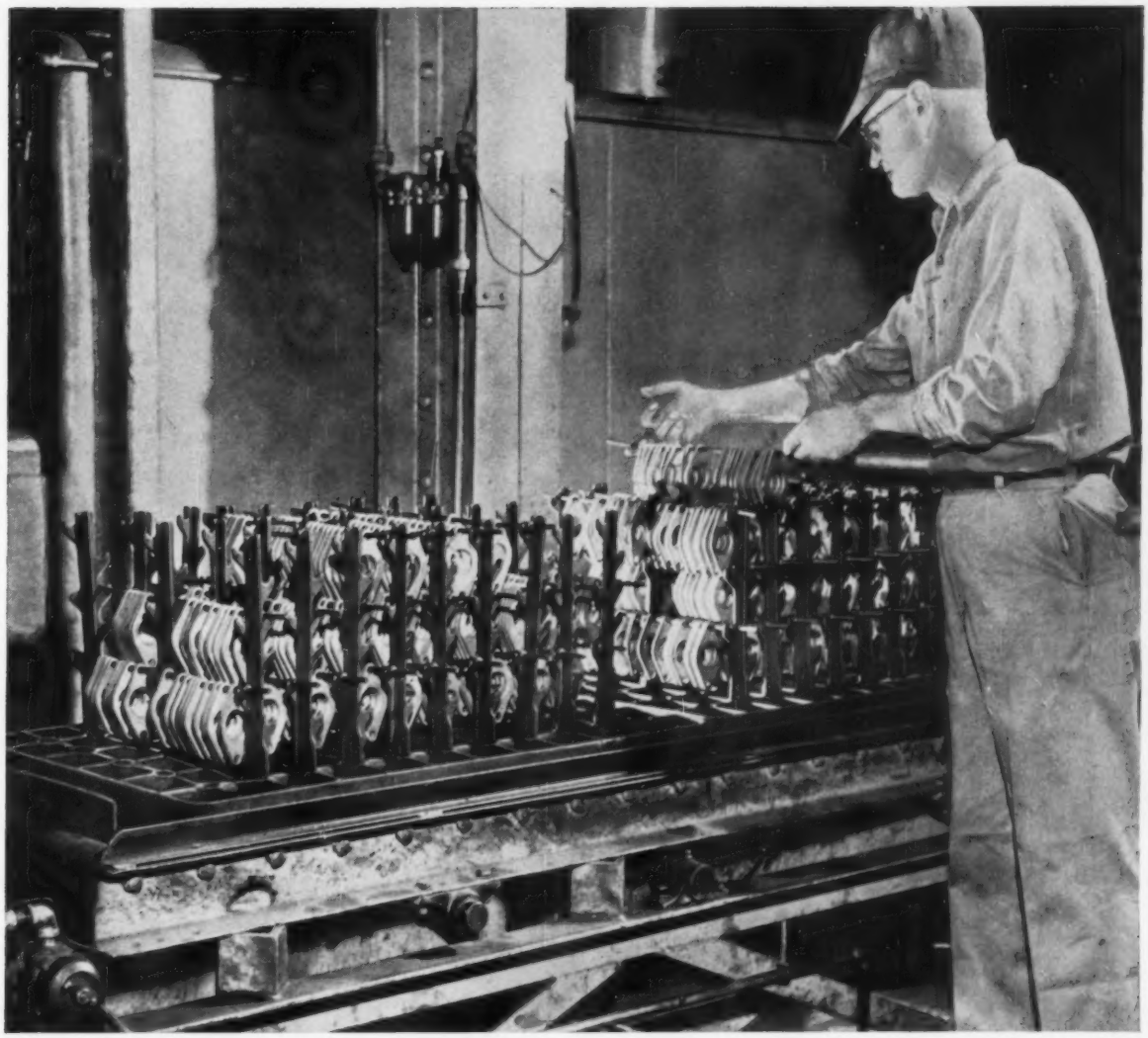
Circle 1582 on Page 48-B



These cast HT alloy work trays carry farm tractor parts through endothermic, ammonia and carburizing atmospheres. Conveyor mechanism has a loading section that can be raised or lowered pneumatically, simplifying handling problem.

Cast high-nickel alloys...for outstanding performance in heat treating service

Work trays . . . loading fixtures . . . furnace parts . . . cast of Type HT* high-nickel alloy withstand 1650°F carbonitriding atmospheres.

Made at a well-known automotive plant, these farm tractor parts are destined for mass heat treating in a single, gas-fired carbonitriding furnace. Temperatures often go as high as 1550° to 1650°F, with cycles varying from 1½ to 5 hours.

To withstand these severe operating conditions, work trays and loading fixtures such as basket carriers, roller rails, rollers, are made of cast Type HT high-nickel alloy. So are other vital furnace parts—rail supports, roller rail spreaders, chain guides and fans.

With its excellent high-temperature strength—its casting ease and economy—Type HT high-nickel alloy is ideal for such heat treating fixtures. This austenitic alloy resists carburization—withstands thermal shock in reducing, oxidizing and nitriding atmospheres.

Type HT alloy is just one of a family of austenitic casting alloys whose high nickel content—*over 35%*—puts them in a class by themselves for heat treating service. Each has outstanding resistance to sustained high temperatures, thermal fatigue and most furnace atmospheres.

To help you select the best possible alloy, we offer the comprehensive booklet, "Heat Resistant Castings, Corrosion Resistant Castings... Their Engineering Properties and Applications." You'll find it useful when considering such design factors as sizes, shapes, atmospheres, load or cycling requirements. It's yours for the asking. *A.C.I. designation

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Circle 1584 on Page 48-B

Corrosion . . .

cause of their excellent mechanical properties and low cost, stainless steels represent an important canning material for reactors using CO_2.

Fuels must be considered in the event of can failures. Uranium is the most popular in gas-cooled reactors. Its oxidation is perceptible in CO_2 at 300° C. (570° F.) and becomes rapid at 500° C. (930° F.). Uranium oxide fuel would not present a problem. Other possible fuels, as carbides and intermetallics, have not been fully investigated.

Structural materials are various steels in the Calder Hall type reactor. Up to 400° C. (750° F.), the oxide (FeO, Fe_3O_4, Fe_2O_3) formed in CO_2 represents only a few microns metal loss per year. A steel containing 1% Cr and 0.5% Mo is the first selection in the 420 to 570° C. (740 to 1060° F.) range.

Pure helium would not present a corrosion problem, but the impurities in the gas would need to be removed. Nitrogen could be used with graphite, beryllium, magnesium or aluminum. Hydrogen forms hydrides with uranium and zirconium, and reacts extensively with graphite at 950° C. (1740° F.) to form methane.

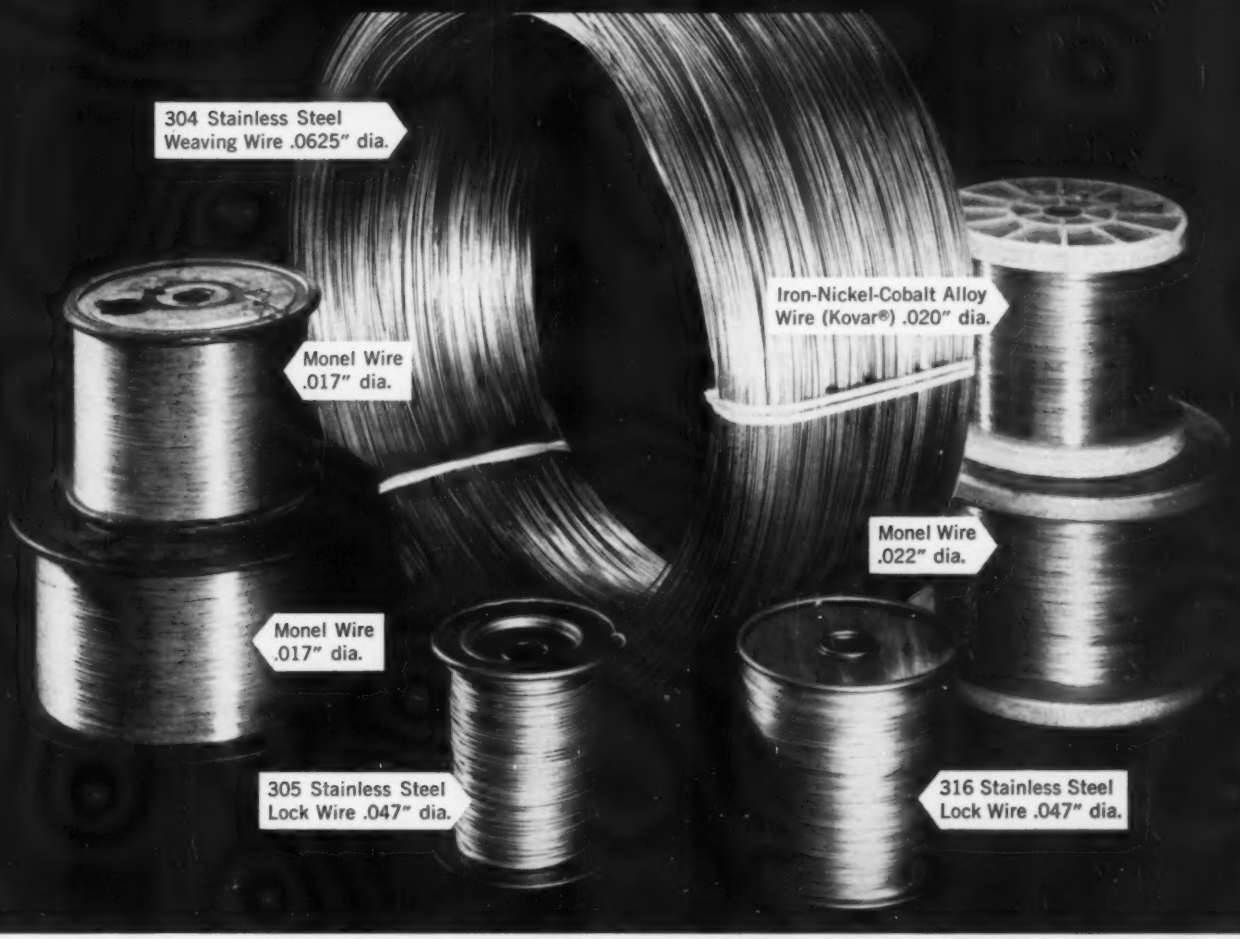
F. H. Beck

Nitriding Titanium

Digest of "Nitriding Phenomena in Titanium and a Titanium Alloy", National Bureau of Standards Report, April 1960.

Fuel control valves for jet engines of carrier-based aircraft have been experimentally produced from unalloyed titanium, and nitrided to harden the surface. Such parts have lasted well in service.

As far as experimental work is concerned, over 300 specimens (representing pure titanium and 6 Al, 4 V titanium) were used in the experiments. They were nitrided in purified nitrogen at 1800° F. for 4, 16, 24, 48, 96 and 168 hr. to obtain data on the relation between case thickness and duration of the treatment. After the nitrided specimens had cooled to room temperature, metallographic examination showed that the nitrided surface layer that forms on the 6 Al, 4 V titanium alloy is



How would you anneal these 5 types of alloy wire?

The various types of alloy wire in this photograph are manufactured for specialized applications by the Riverside-Alloy Metal Division, H. K. Porter Company, Inc. They range from stainless steel, for aircraft industry use, to monel metal and an iron-nickel-cobalt alloy with thermal expansion characteristics suitable for sealing to hard glasses. Annealing temperatures range from 1450 to 2150 F, close control being necessary to maintain wire quality, measured by elongation, grain structure and tensile strength. The wire is annealed continuously—normally in a disassociated ammonia atmosphere.

Experience has proved that electric furnaces equipped with GLOBAR® silicon carbide heating elements offer the cleanliness and capability for precise temperature control needed in this operation. The GLOBAR elements easily provide the maximum 2150 F heat—in fact, can be used with safety to above 2750 F. One of the furnaces used, with 13½" thick walls of refractory insulating brick, has required no maintenance of the lining over a 10-year period—pointing up the mild conditions to which insulating brick are subjected with this type of heat. With the low heat capacity of the insulating brick, it is possible to drop temperatures rapidly in going from the high to low end of the range.

The many advantages of heating with GLOBAR elements, as illustrated in this particular case, often more than cancel out possible differentials in Btu costs between electricity and other fuels. Why not investigate with your furnace builder—or write to Refractories Division, Globar Plant, Dept. MP-41, Niagara Falls, N. Y.

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Nitriding Ti . . .

thinner than that which forms on the unalloyed titanium. In addition, elongated nitride grains form in the alloy and penetrate as far as the center of the core. Figure 1 illustrates the appearances of the cases. Though the impact strength of titanium was not impaired by nitriding, the 6 Al, 4 V titanium alloy suffered a serious reduction in its impact resistance. The elongated nitrided grains in the alloy apparently act as stress raisers to reduce impact strength.

Subsequent examination of the alloy with an electron-probe microanalyzer indicated that the vanadium content in the elongated grains was only half of that in the surrounding matrix. Also, there was no gradient in vanadium composition in the matrix (in the vicinity of the boundary). Rather, there was an abrupt change in vanadium content from the amount in the nitride grain to the amount in the matrix.

The total case thickness increased with increase in nitriding time, following a parabolic law. It reached a thickness in excess of 0.008 in. in 168 hr. This behavior is contrary to that previously observed by other investigators, who found that titanium, nitrided in ammonia, attains a maximum case of approximately 0.004 in.; further treatment reduces case thickness.

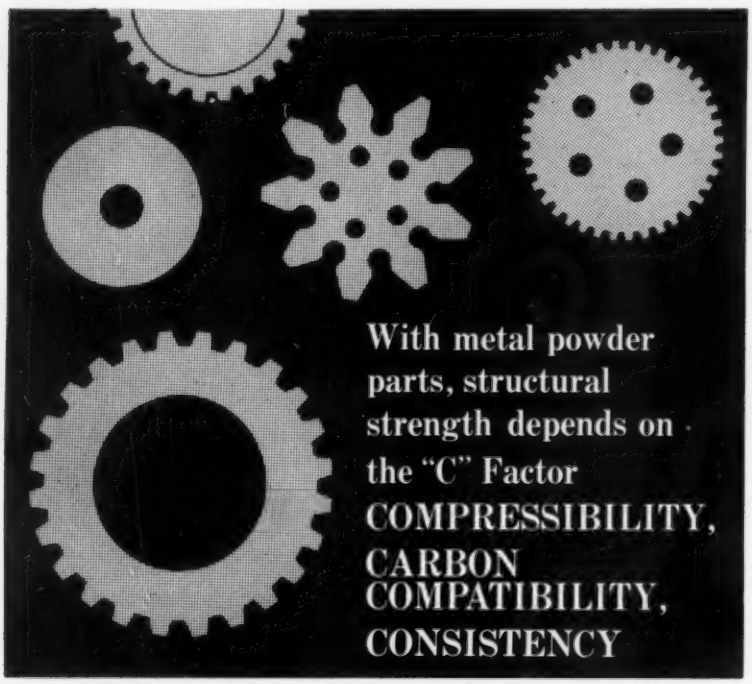
C.R.W.

Fig. 1 — Nitrided Cases After 48 Hr. Pure titanium, above; 6 Al, 4 V titanium, below. Note that the case on the alloy is thinner than the case on the pure titanium. Etchant: 1 part HF, 12 parts HNO_3, 87 parts water. 200 ×

Bearing Steel Properties

Digest of "Effect of Hardness and Other Mechanical Properties on Rolling-Contact Fatigue Life of Four High-Temperature Bearing Steels", by T. L. Carter, E. V. Zaretsky and W. J. Anderson, NASA Technical Note D-270, March 1960.

AS PART OF A CONTINUING PROGRAM to improve the operating life of rolling-contact bearings, attempts are being made to correlate various material properties with the endurance of the bearing elements.



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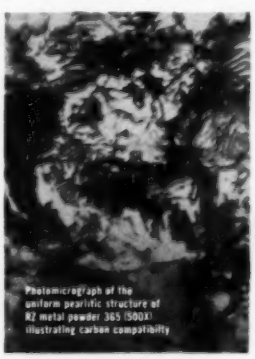

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Circle 1588 on Page 48-B

Bearing Steels . . .

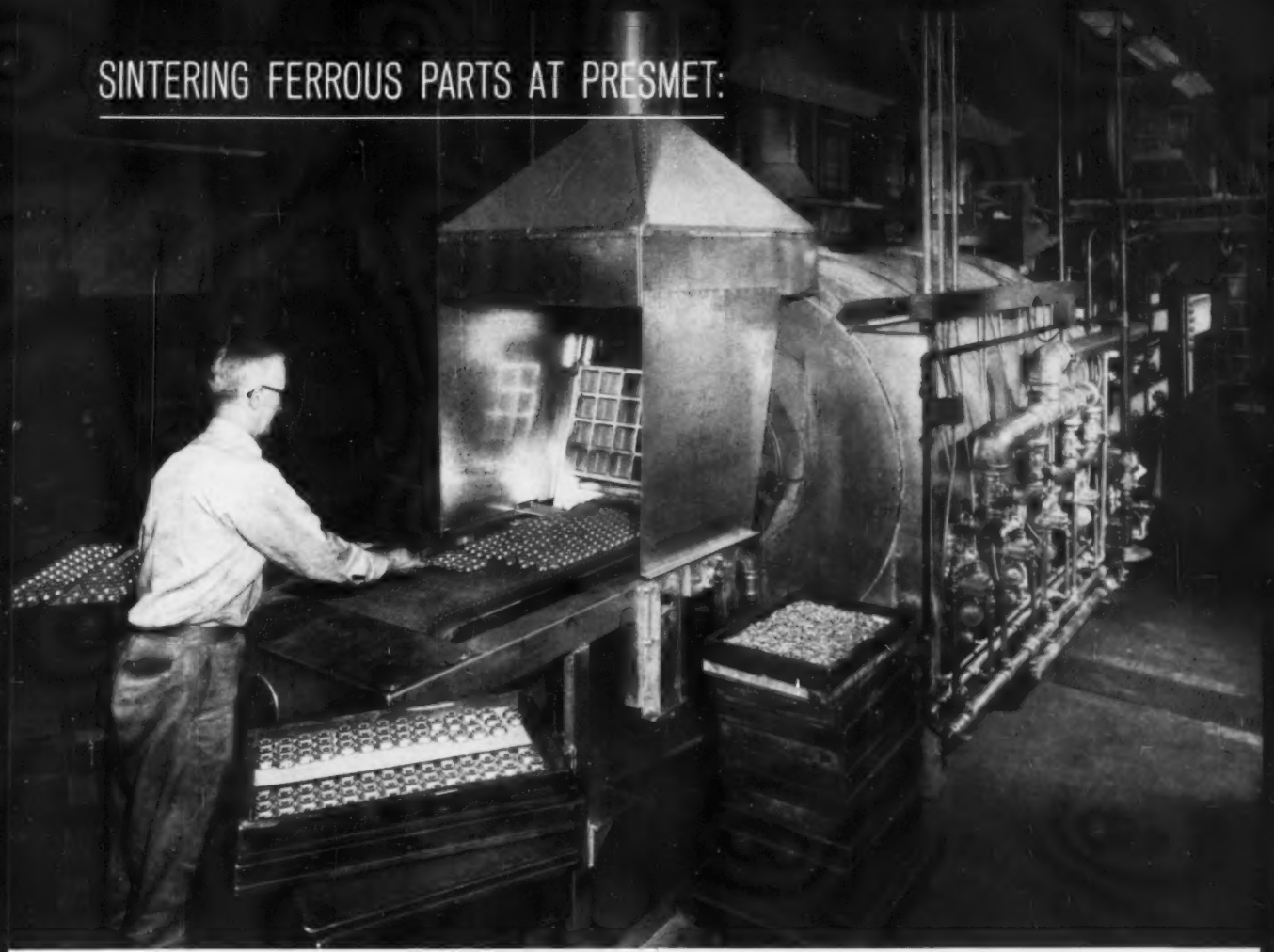
In the present work, the properties concerned are those related to hardness. These are resistance to plastic deformation and wear, percent retained austenite, elastic limit, yield strength, and ultimate strength in both tension and compression.

The apparatus used consisted of the rolling-contact fatigue spin rig and the five-ball fatigue tester. In the former, two balls are driven at high speed on the inner surface of a race cylinder by an air jet; loading is by centrifugal force. In the latter, a driven test ball is mounted on four lower balls, positioned by a separator and free to rotate in an angular-contact raceway. Specimen loading and drive is applied through a vertical shaft. By varying the pitch diameter of the lower balls, the bearing contact angle may be altered. Lubricant flow rate was carefully controlled and the temperature was measured by a thermocouple in contact with the raceway.

Ball bearings were made from four toolsteels: A.I.S.I. M-1, M-50, Halmo and WB-49. Race cylinders were all heat treated to the same hardness (Rockwell C-62 to 63) and the balls were heat treated in groups to various hardnessess from Rockwell C-55 to 68.

The M-1, M-50 and Halmo balls were tested in the spin rig and the WB-49 balls in the five-ball rig. For all four steels, fatigue life increased continuously with increasing material hardness. Values of the load-carrying capacity were calculated, and showed a corresponding improvement, which was in the order of 30 to 100%. No *maximum* fatigue life or load capacity was observed at intermediate hardness levels, which is in direct contrast to the compressive and tensile strength properties for the M-1, M-50 and Halmo steels. This may be due to a true lack of correlation between fatigue life and mechanical strength, or to errors in loading of the hardest tension and compression specimens.

Evidence in support of the latter suggestion was obtained from the plastic deformation studies, which showed increasing resistance with increasing hardness, the hardest specimen of each alloy giving the least volume of plastic deformation. Wear measurements gave similar



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As a contract sintering specialist, Presmet Corporation of Worcester, Mass. uses this Harper Mesh Belt Furnace to sinter iron and iron graphite parts as well as to infiltrate them with brass or copper.

Placed on the wire mesh belt, green compacts move successively through a 1500° F gas-fired binder burnoff chamber, a volatile-vent chamber, a 2050° F high heat chamber equipped with silicon carbide elements, an insulated pre-cooling chamber and a water jacketed cooling chamber.

Designed specifically for sintering, the Harper furnace includes several unique features for positive counterflow of atmosphere gas, proper disposal of volatiles, easy ash removal, quick duplication of belt speeds, and accurate control of temperature profile.

Says Presmet, "This furnace has fully measured up to expectations in maintaining product quality. With volatiles completely discharged from the vent chamber, parts emerge from cooling soot-free. A high degree of dimensional and strength control is achieved."

For detailed information on Harper Mesh Belt Sintering Furnaces such as this, request Bulletin MSF-361. Literature on other types of furnaces shown below is also available promptly. Write for one or more of the bulletins listed. Harper Electric Furnace Corp., 40 River St., Buffalo 2, N. Y.

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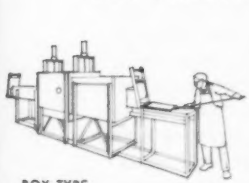
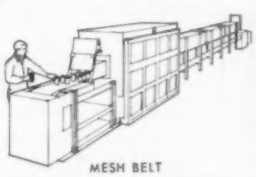
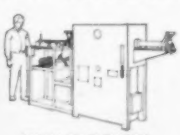


BOX TYPE
- ☐ Sintering — Bull. BFS-360
- ☐ Dry Hydrogen — Bull. HB-460

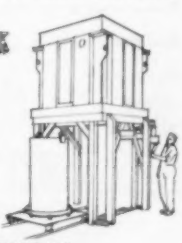


MESH BELT
- ☐ Sintering — Bull. MSF-361
- ☐ Straight Thru — Bull. MB-960
- ☐ Hump Type — Bull. HMB-960

HARPER FURNACES



TUBULAR ELEMENT
- ☐ Globar — Bull. GT-1059



ELEVATOR
- ☐ Bull. EF-260

TUBE
- ☐ Graphite — Bull. CT-1159
- ☐ Zoned — Bull. ZT-361

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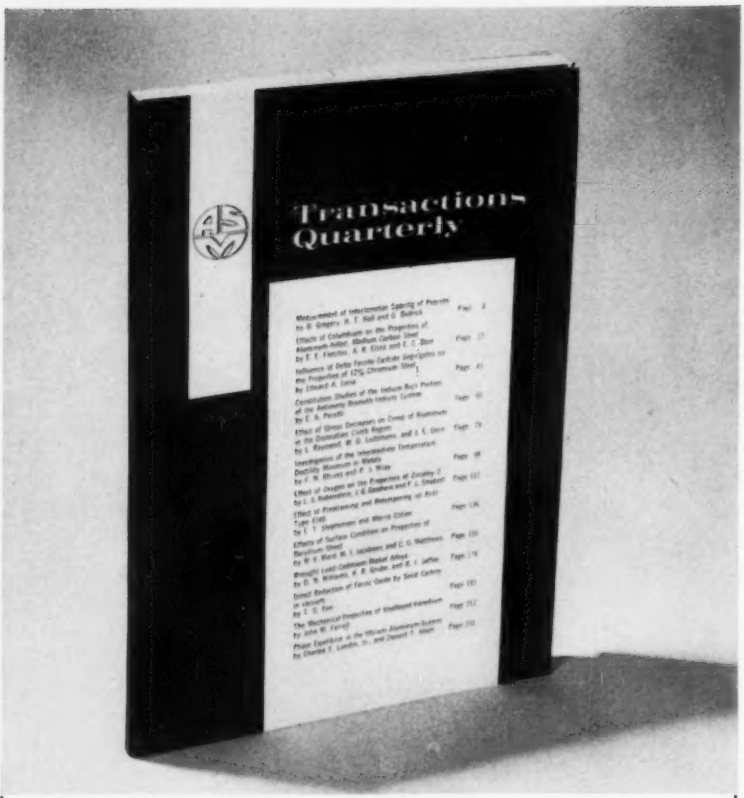

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Bearing Steel . . .

results, volume of wear decreasing with increasing ball hardness.

Only minor differences were noted in the microstructures of the balls tempered to the various hardness levels. The softer balls tended to have larger, more numerous precipitated carbides and greater definition of the tempered martensite. They also had the lowest percentage of retained austenite. If retained austenite has a deleterious effect on mechanical properties, as has been suggested, it was of smaller magnitude than the beneficial effect of higher hardness in the present experiments.

The authors concluded that rolling-contact fatigue life and resistance to permanent deformation increased with hardness for the four steels tested. Hence, hardness or a simple plastic deformation test with a rolling-contact element may give a useful estimate of fatigue behavior.

R. C. A. THURSTON

Defects in Railroad Wheels

Digest of "Study of the Defects That Originate and Develop in the Treads of Railroad Wheels During Service", by J. M. Wandrisco and F. J. Dewez, Jr. A.S.M.E. Paper 60-RR-1 presented at the A.S.M.E.-A.I.E.E. Railroad Conference, Pittsburgh, April 1960.

RAILROAD WHEELS are subject to dynamic stresses produced by rolling and lateral thrust loads and to the thermal effects that result from the friction created during braking; both conditions give rise to various defects in service. This paper presents the results of an examination of a number of damaged heavy-duty wheels, supplemented by full-scale laboratory tests.

Thermal gradients can cause both microstructural and residual stress changes. The microstructures produced by severe braking from high speed are typical of those found in steel weldments. Brake shoe metal is fused to the wheel surface, and immediately below is a high-carbon martensitic layer, indicative of carbon diffusion from the brake shoe. The next layer consists of mixtures

KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many who may find it useful to review fundamentals from time to time.

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What is hardenability and how does it differ in carbon and alloy steels?

Hardenability can be defined as the capacity of steel to develop a desired degree of hardness, usually measured in depth. It is produced by special heating and cooling. Carbon steel, except in small sections, will normally harden to a depth slightly below its surface, while alloy steel can, under certain conditions, harden uniformly through its entire cross-section.

Surface hardness obtainable after quenching is largely a function of the carbon content of the steel. Depth hardness, on the other hand, is the result of alloying elements and grain size, in addition to the carbon present in the steel.

In general, where hardenability is the prime consideration, it is not too important which alloy steel is used, just so long as there is sufficient carbon present to give the prescribed hardness, and there are enough alloying elements to quench out the section. It is not considered good practice to alloy a small section excessively, since excessive use of alloying elements adds little to the properties and can, in some instances, induce susceptibility to quenching cracks.

There are, of course, numerous cases where factors other than hardenability must be considered; such factors as low-temperature impact, heavy shock, creep-resistance, and the ability to resist temper brittleness. Through-hardening, therefore, is not always desirable. For example, shallow hardening is often necessary in shock applications, because a moderately soft core is essential.

This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts about Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

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Circle 1590 on Page 48-E

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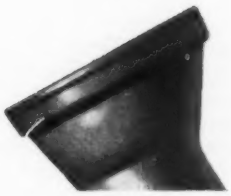

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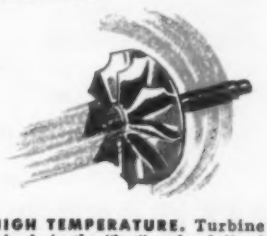

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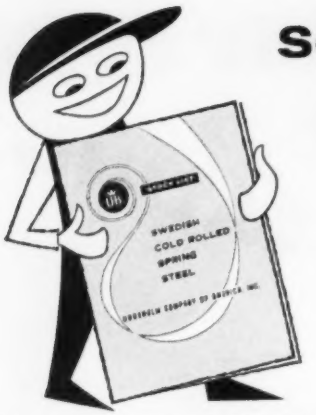

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District Engineers in Principal Cities

Circle 1593 on Page 48-B

Defects . . .

of nodular pearlite, martensite and traces of bainite, the percentage of nodular pearlite increasing with depth to 100%. This is followed by a marked change to a spheroidized microstructure, and finally, there is a tempered area (the depth of which depends on the temperature gradient), which actually blends into the original microstructure of the wheel.

The residual stress system induced by braking will normally consist of a hoop tensile stress in the outer layers, balanced by compressive stress in the inner layers. The magnitude and distribution, however, will also depend on volumetric transformation changes, stress relaxation and strength at elevated temperatures, the Bauschinger effect, and the initial stress system. The tread defects caused by thermal stresses are of at least three types – thermal checks, "sudden"-type thermal cracks, and fatigue-type thermal cracks.

Thermal checking or "crazing" is believed to be due chiefly to tensile stresses developed within the carbon-diffusion layer by austenite transformation. Tensile stresses produced by the tempering of martensite also cause thermal checks, wheels of higher carbon steel being more susceptible. The checks, however, do not progress beyond the hypercritically heated zone, and are being continually worn away and replaced.

Sudden-type thermal cracks are the most hazardous, and may initiate an explosive, brittle failure. They are relatively large and are believed to form when residual tensile stresses, developed in the wheel rim as the result of braking, exceed the brittle fracture strength of the steel. Again, the higher-carbon steels (which also have lower notch toughness) are more susceptible. In full-scale tests, a single severe braking was sufficient to produce such cracks in Class CR wheeels (0.67 to 0.77% C), whereas repeated brakings were required in the case of Class BR wheels (0.57 to 0.67% C) and Class AR wheeels (0.57% C max.).

Fatigue-type thermal cracks form more slowly, but propagate as deeply as sudden-type thermal cracks. Like the latter, they are oriented in a

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Entries should carry a label on the *face of the mount* giving:

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The name, company affiliation and postal address of the exhibitor should be placed on the *back of the mount* together with a request for return of the exhibit if so desired.

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Class 11. Electron micrographs using replicas
Class 12. Electron micrographs (transmission)
Class 13. Color prints in any of the above classes
Class 14. Results by unconventional technique

AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which in the opinion of the judges closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $500 from the Adolph I. Buehler Endowment will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters.

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Circle 1594 on Page 48-B

Defects . . .

radial-axial plane, but are associated with frequent brakings of rather low energy dissipation. Usually less than 1/16 in. of metal at the tread surface of the wheels containing such cracks has been heated above the lower transformation temperature. Such cracks are believed to be caused by cyclical thermal stresses developed by alternate heating and cooling, and to be independent of rolling loads. Evidence supporting the latter belief is that most cracks start at the tip of the flange where the wheels do not contact the rail, or near the front edge of the tread where rail contact is infrequent.

In view of the importance of elevated-temperature strength and notch toughness, several wheels of alloy steel with superior properties were tested. The results confirmed the expected higher resistance of these wheels to sudden-type thermal cracking and to explosive failure. Unfortunately, service tests indicated that they were only slightly more resistant to fatigue-type thermal cracking than carbon steel wheels.

Rolling loads cause a defect known as "shelling", a defect characterized by the expulsion of pieces of metal from the tread surface. Cracks form at 30 to 50° to the tread surface, and propagate by fatigue into the rim. When they meet, the metal between is loosened and subsequently expelled. They are believed to be caused by the repeated application of shear stresses as the wheels rotate, and their formation is accelerated by the effects of breaking friction, which produces relatively soft, tempered areas. The maximum shear stress under static loading occurs at some distance beneath the contact area, and at 45° to the surface. When the friction forces due to rolling load are also considered, the maximum shear stress can be up to 50% higher, and can occur in the contact area. Furthermore the plane of this stress may be changed under rolling load; this could account for the variation in the orientation of the cracks. Examination of random samples from shelled wheels gave no indication that shelling cracks originate beneath the tread surface.

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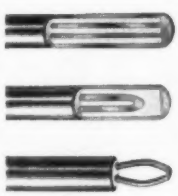

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Circle 1595 on Page 48-B

Drawing Aluminum

Digest of "Drawability of Sheet Aluminum Alloy 5457", by Robert W. Bund. Paper No. 59-A-310 presented at the annual meeting of the American Society of Mechanical Engineers, November 1959, Atlantic City, N. J.

THE DRAWABILITY OF SHEET METALS is an important subject, and one that is but little understood. In particular, tests are lacking that will allow the engineer to predict the performance of different alloys and tempers of sheet in various forming and drawing operations. Present tests for drawability are comparative in nature and are classed as simulative tests and fundamental tests. Simulative tests include the Erichsen test, bend tests and the various cup drawing tests. Fundamental tests include the tensile test, hydraulic bulge tests and strain hardening tests.

In this article, an empirical relationship between drawability and strain hardening is developed. The basic strain hardening curve for alloy 5457 is obtained from measurements of true stress and the corresponding strains. True stress is calculated from simultaneous measurements of load and cross-sectional area and plotted against reduction in diameter. The limiting points on the strain hardening curve are the yield strength of the annealed metal and the ultimate stress at which internal fracturing begins. Graphically, the latter point coincides with deviations from linearity in the strain hardening curve (or the point at which stress begins to increase more rapidly than strain).

Having established the strain hardening curve and the true ultimate strength of the alloy, the drawability of various tempers of 5457 can be estimated from a knowledge of their yield strengths. This is performed graphically on the strain hardening curve, assuming equivalence between reduction in diameter in a tensile test and reduction in diameter in drawing. The graphical solution is a form of proportionate analysis in which strain hardening, as represented by prior deep drawing or sheet temper reductions, reduces the capacity of the metal for further drawing by an amount proportional to the total deformation obtainable from the alloy in the annealed state. Thus, the sum of this and of succeeding cold drawing operations cannot exceed the total deformation capacity of the annealed temper sheet.

The analysis is useful in estimating permissible reductions for multiple drawing operations on various tempers of sheet. From the results, the lower the yield strength of a particular alloy, the greater its drawability should be. The technique can also be used as an aid in selecting intermediate annealing points for multiple drawing operations that involve total reductions greater than the deformation capacity of the alloy.

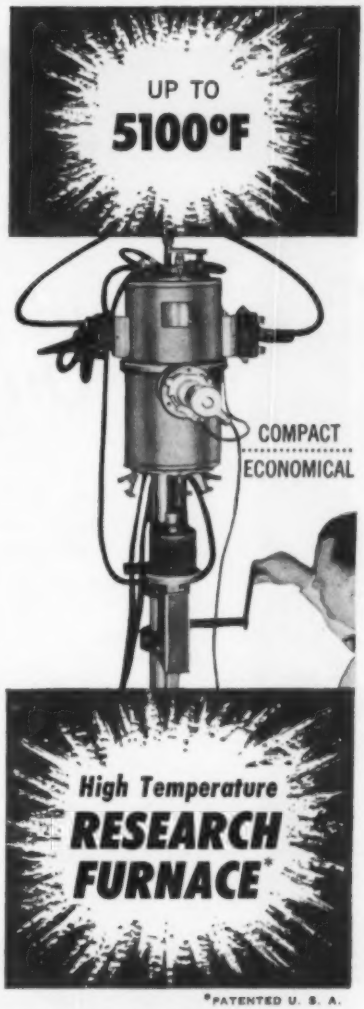
W. A. ANDERSON

High-Pressure Blast Furnace

Digest of "The Ultra-High-Pressure Blast Furnace", by Owen R. Rice, Consultant, Koppers Co., Inc., Pittsburgh, October, 1959.

VARIOUS EXPEDIENTS for increasing the productivity and lowering the cost of blast furnace operations have attracted attention in recent years. For example, about one fifth of the larger iron blast furnaces in this country now operate with higher than normal top pressures. These pressurized blast furnaces operate at back pressures of 1.5 to 10 psi. Similar practices are employed in other countries to minimize flue dust losses and to increase production rates. This article speculates on equipment changes that might be required and the advantages that might be gained by operating at top pressure of 40 psi. as measured by gage. Unfortunately, there are comparatively few data on which to base an engineering study of the effects of such significantly higher top pressures. Therefore, the argument that ultra-high pressures would be desirable is based on experience with conventional pressurized furnaces and on the known effects of pressure on gaseous reduction of iron ore.

Comparisons of blast furnace operations are usually based on Freyn ratings. On this scale, a rating of 100% corresponds to a consumption of 6300 lb. per day per sq.ft. of hearth area of coke containing 86% carbon. Higher ratings are desirable because they indicate a furnace produces more CO for re-



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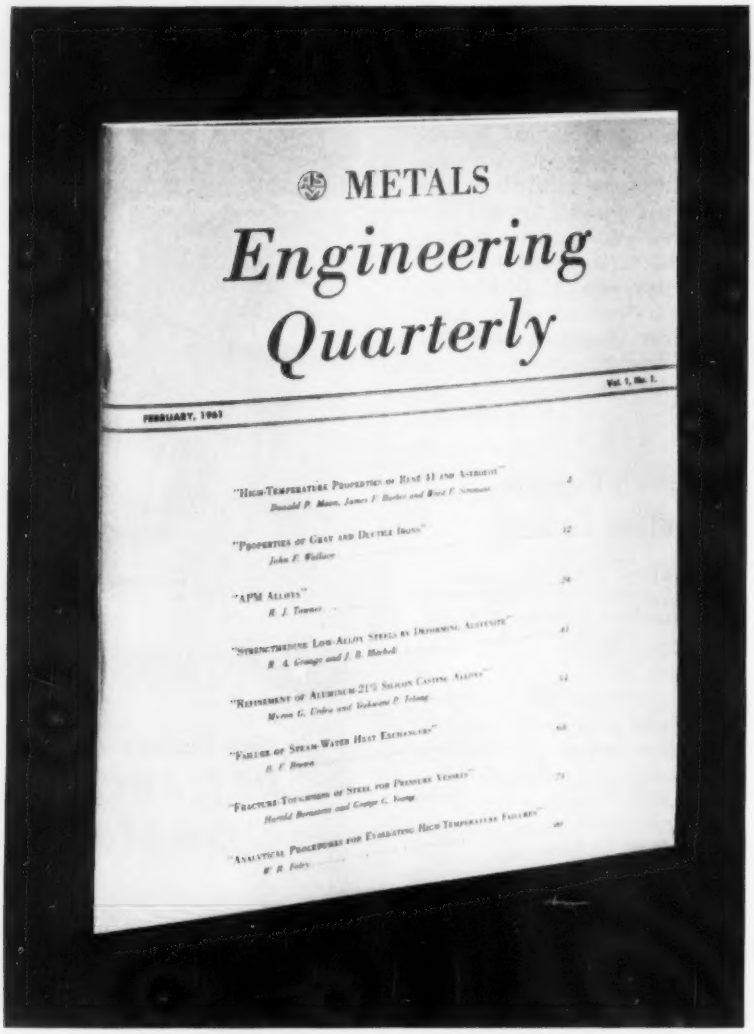

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Blast Furnace . . .

ducing iron ore. Rice shows that the Freyn ratings of 16 blast furnaces operating at an average top pressure of 8 psi. average 110 compared to an average of 94 for 60 unpressurized furnaces. These Freyn ratings show the trend for improved performance at high top pressure. Strict comparisons between the two groups of furnaces are unjustified because of variation in charge materials, moisture content of the blast, and missing data on delay time.

In 1936 Diepschlag published information about the effect of various pressures and temperatures on the gaseous reduction of a particular iron ore. The data for CO, the principal reducing agent in a blast furnace, are of particular interest:

Furnace Pressure	Top Pressure	Reduction in 30 Min.
1.63 atm.	1.8 psi.	34%
1.84	5	39
2.18	10	49
2.86	20	69
4.22	40	76
5.58	60	83

Diepschlag determined these values at 1100° F., a reasonable approximation of the temperature at which reduction of iron by CO takes place in a blast furnace. He also showed that pressurization had similar effects on reduction rates at other temperatures. Consequently, Rice suggests that operating a blast furnace at a top pressure of 40 psi. should double the rate of iron ore reduction. If so, a conventional furnace producing 2000 tons of iron per day from suitable raw materials might turn out 4000 tons per day at a top pressure of 40 psi.

Since doubling the production rate of a large blast furnace would pose many engineering problems, completely new installations would be more practical than additions to existing furnaces. Rice describes a proposed 4000-ton-per-day ultra-high-pressure furnace which would be built on a 28-ft. hearth. It would be charged with beneficiated sinter (preferably self-fluxing) in lumps up to 2 in. and well-screened coke. Two small bells acting as gas locks would replace the conventional big bell and distributor. Tubs holding 523 cu.ft. would charge material, through the two bells, every 2 min. As the charge entered the 7-ft. di-

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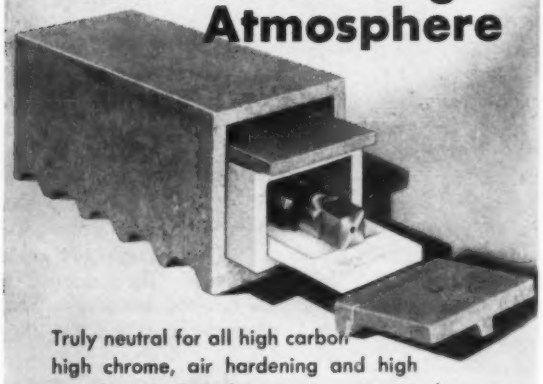

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Circle 1576 on Page 48-B

Blast Furnace . . .

ameter throat, it would fall beneath the bells and on a pile held by retaining rings. The retaining rings, arranged in echelon, would control the shape and height of the pile at the top of the stock column. Charging cycles would be controlled by photoelectric stock gages, supplemented by a mechanical stock rod. The charging system would handle 10,000 tons daily. Abrasion resistant materials would be used to face hoppers, bells and throat. These would probably be replaced as a preassembled unit to avoid delays.

Higher pressures raise the temperature at which moisture condenses. Even though the proposed furnace would operate at higher gas velocities, the effective height of the shaft would probably have to be reduced about 14% to prevent condensation at the top. Rice proposes to make the distance from tuyeres to stock line 72 ft. instead of the 82 ft. typical of most 28-ft. hearths.

The furnace shell and hearth jacket would be cooled by external vertical water panels because the elimination of perforations for cooling elements would provide more strength. The hearth jacket would be made of 2.5-in. plate to chill any iron leaking through the refractory. Carbon walls extending to the mantel would minimize the need for internal cooling. The hearth bottom would be cooled by air forced through ducts in the concrete pad under the ceramic hearth-bottom blocks.

The wet-type dust catcher on the proposed furnace would be smaller than normal, but of conventional design. The gas cleaner consists of automatically adjustable orifice plates in the downtake gas main following the dust catcher. The gas cleaning system serves two purposes. It is the back-pressure device imposing 40 psi. on the top of the furnace, and it uses the pressure differential to clean the gas. Water is introduced, at 1000 gal. per min., above the top orifice plate and passes with the gas through the orifice plates. Because of the pressure drop, about 39 psi., the device is expected to lower dust counts to 0.001 grains per cu.ft.

Stoves with checker areas of 500,000 sq.ft. and burner capacities of 50,000 cfm. are expected to be structurally stable at temperatures up to 2300° F. Valves and fittings are designed for blast pressures above 60 psi. The stoves are intended for heating the blast to 2000° F. for 60 min. or to 1800° F. for 75 min. The turboblower installation would deliver 200,000 standard cu.ft. of air per min. at 60 psi.

The materials storage system would have to be changed and probably mechanized or automated. Bins for one-day ore storage at the stockhouse would become hoppers with 8-hr. capacities, fed by belt conveyers. Similarly, coke bunkers would probably store 3-hr. rather than 8-hr. quantities.

In order to handle twice as much iron, the cast house facilities (taphole, trough, dam, and so forth) would be doubled. Presumably a better taphole mud, perhaps a mixture of clay, ganister and tar, would be needed to resist erosion induced by higher pressures and larger casts.

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Circle 1577 on Page 48-B

Determining Thermoelastic Properties

Digest of "Determining the Thermoelastic Properties of Metals and Alloys", National Bureau of Standards, December, 1959.

TWO SIMPLE DYNAMIC TECHNIQUES have been adapted by the National Bureau of Standards to deter-

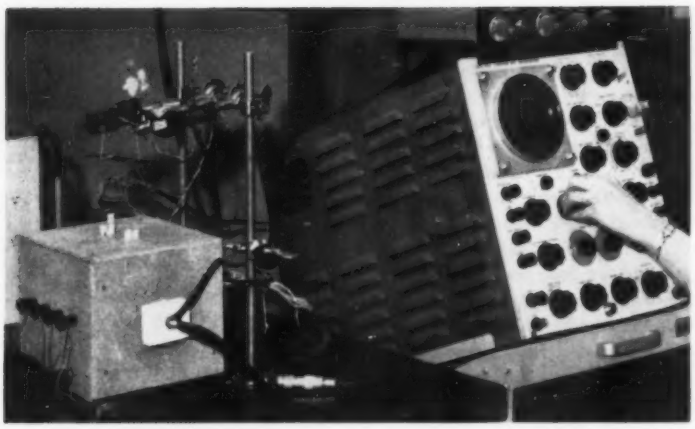

Fig. 1 — Device for Determining the Thermoelastic Properties of Metals and Alloys by Sonic Vibration. The specimen being tested can be seen hanging by two strings above the furnace.

mine the thermoelastic properties of metals and alloys. A pendulum assembly is used to test wire specimens, and a sonic vibration apparatus (see Fig. 1) is used for testing rods and prisms.

Equipment used in the pendulum method consists of an oven, photoelectric cell and lamp, timer, counter, and electronic temperature recorder operating up to 525° F. A frame about the oven supports a steel rod that extends vertically through a hole in the top of the oven into the heat chamber. The wire specimen is suspended from a chuck on the lower end of the rod. Another chuck grips the lower end of the specimen. When the upper portion of the rod is twisted slightly, the pendulum oscillates about the axis of the specimen. The photoelectric cell and lamp, mounted just outside the oven, are aligned with two holes in the oven wall. Once in each half cycle of oscillation, light from the lamp strikes a small mirror attached to the pendulum assembly, and is reflected back to the cell. The cell, thus energized, operates the counter and timer until a predetermined number of oscillations is registered. The shear modulus of the wire is then computed from the resonant frequency derived for the specimen, and the dimensions and masses of the pendulum assembly. Frequency range is from a fraction of a cycle to 10 cycles per sec.

In the sonic vibration method, the rod or prism specimen (about 6 in. long) is suspended from an electromagnetic driver by two asbestos strings and enclosed in a furnace which operates up to 1000° F. The specimen is excited to its resonant

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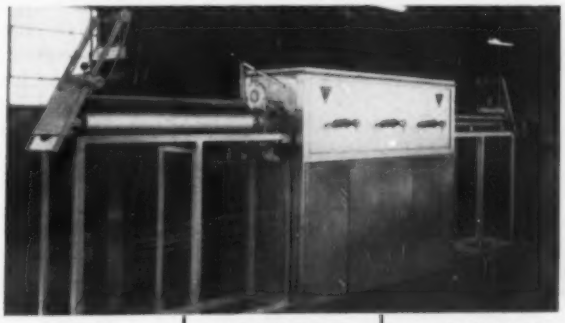

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Circle 1579 on Page 48-B

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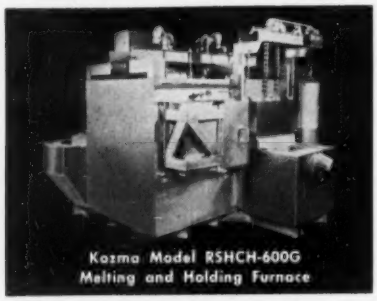

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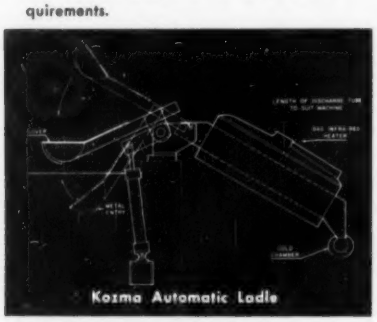

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Circle 1580 on Page 48-B

Thermoelastic . . .

frequency by the driver and a variable audio oscillator. A crystal pickup detects the vibrations which are shown on a cathode ray oscilloscope. Oscillator frequency is then adjusted to the frequency of the specimen and indicated by the amplitude of the oscilloscope trace. This adjusted frequency is measured with an electronic events-per-unit-time counter. From the measurements thus obtained, Young's modulus can be computed for rod specimens. In using the apparatus for tests on rectangular prism specimens, the prisms can be made to vibrate either in tension or torsion, so that both Young's modulus and the shear modulus may be determined without changing the mode of suspension.

C.R.W.

Resistance to Cyclic Temperatures

Digest of "'Superhigh Plasticity' of Commercial Iron Under Cyclic Fluctuations of Temperature", by M. G. Lozinsky and I. S. Simeonova, *Acta Metallurgica*, November 1959, p. 709.

TENSILE TEST PIECES were cut from Armco ingot iron plate (0.03% C) and from vacuum-melted iron (0.006%), loaded steadily at 500 psi., but heated electrically by fluctuating currents so the midlength of the specimen ranged rapidly between 1475 and 1560° F. (800 and 850° C.) and between 1475 and 2000° F. (800 and 1100° C.)

Under such conditions all samples of pure iron necked down at midlength. This also was true of the Armco iron whose midlength temperature fluctuated between 1475 and 1560° F. However, when the latter had a higher fluctuating temperature, two necks appeared on either side of midlength at positions corresponding to temperatures within the range of 1325 and 1560° F. (720 and 850° C.). Total deformation in these necks was several times greater than in the middle of the specimen which was at a higher temperature.

Theoretically, this is explained by the authors by saying that even though the *average* carbon content of Armco iron is 0.03%, autoradiography using radioactive carbon indicates micro regions at grain boundaries very considerably above this average – in fact the carbon atoms in alpha solid solution are mainly situated at the grain boundaries. The hypothesis is that the reversible alpha to gamma transformation therefore takes place locally in high carbon metal with the 1325 to 1560° F. range, with corresponding changes in lattice parameters and volumes which weaken the coherency of the aggregate. Hence the dual necks in Armco iron; hence no dual necks in carbon-free iron.

Practically, this may help to explain some mysterious failures of such things as jet engine parts, rapidly heated and cooled during several hundred starts and stops, or of parts of internal combustion engines which endure many millions of cycles of temperature during their life.

E.E.T

Degassing Unit for Foundry

Digest of "Degassing of Steel in Vacuum for Use in Aircraft Castings", by J. K. Dietz. Paper presented at the A.I.M.E. 17th Electric Furnace Steel Conference, December 1959, Cleveland.

UNDER GOVERNMENT SPONSORSHIP, Chance Vought Aircraft undertook a program for research and development of large, complex steel castings for aircraft. As part of this program, an investigation of vacuum degassing is being carried out at two foundries, Stanley Foundries of Huntington Park, Calif., and Pacific Alloys of El Cajon, Calif.

As originally conceived, the degassing unit was to be relatively inexpensive compared to a vacuum melting furnace, use the existing equipment to the greatest extent possible, be simple and rapid in operation, and easily installed. Simply described, the unit, as developed so far, is a shell which encloses an induction furnace. To have some operating procedures established prior to the first trial, a number of 200-lb. heats were first tried. The operators soon found that the pressure must be gradually reduced (rather than applying the full capacity of the pump). Otherwise, metal could be thrown out of the pot when the

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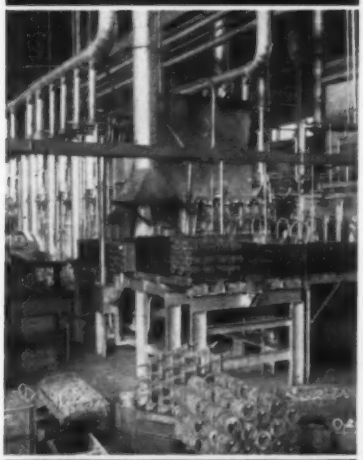

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Circle 1581 on Page 48-B

degassing cycle was started because of the large amount of gas which would be evolved.

Leaks have been a problem. Joints and seals, especially the joint where the cover meets, must be clean, and the furnace must be thoroughly dry. A drying period of 24 hr. under vacuum is required to remove all the moisture after installing a new lining or a patch.

The existing equipment can reach absolute pressure of 600 microns which, according to the latest literature, is not sufficient to achieve a substantial improvement in mechanical properties. The goal is to achieve pressures of 10 to 30 microns. Despite this "inadequate" vacuum of only 600 microns, some improvements have been achieved. The process has been quite successful in reducing the gaseous content of Type 347 stainless steel. In five typical heats, hydrogen was reduced from 4.5 ppm. to 2.4 ppm. on the average. Reductions were also noted in oxygen and nitrogen.

One idiosyncrasy of metal that has been degassed was noted: It exhibits a rather sharp and higher freezing point than does nondegassed metal. This is attributed to the lower oxide content, and must be compensated for when the pouring temperature is estimated.

Work is continuing on this project. The writer concludes that the equipment needs only minor modification to achieve absolute pressures of 20 to 30 microns, and also that the cost of such a unit is within the budget of even a small factory.

C.R.W.

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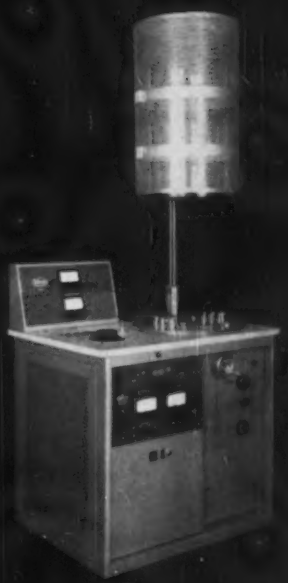

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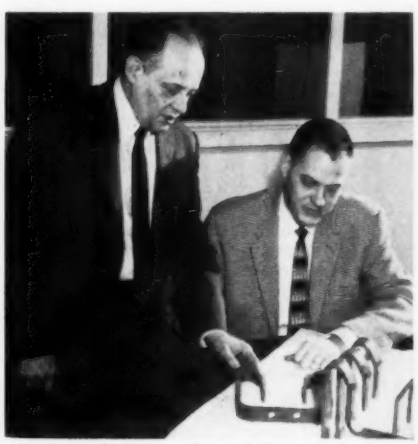
Circle 1583 on Page 48-B

BEHIND THE BYLINES

The problems associated with materials for use at low-temperatures (for missiles and space vehicles using cryogenic fuels) are being faced by Convair-Astronautics in San Diego, Calif. Some of Convair's work in this area is covered by Abraham Hurlich and James Watson in their article on p. 65. Mr. Hurlich (shown below, far right, talking with Editor Gray, center) joined the company more than four years ago after 15 years as chief of the materials engineering laboratory at Watertown Arsenal Laboratories. Now supervisor of the materials research group responsible for the direction of materials research and development, his work centers on extremely low-temperature materials and ablation characteristics at high temperatures. His co-author, Mr. Watson, is staff scientist in the

material research group, as well as Convair-Astronautic representative to the Aerospace Research and Testing Committee of the Aerospace Industries Assoc. He came to Convair after receiving his Ph.D. degree in metallurgical engineering from the University of Michigan in 1958, where he also received his B.S. (1953) and M.S. (1956) degrees.



Zirconium - copper, a new alloy with high strength and high electrical conductivity, is described by A. E. Moredock and D. K. Fox (p. 75), both in the materials engineering department of Westinghouse. Since his graduation from Carnegie Tech in 1929, Mr. Moredock has accumulated broad experience in the nonferrous field, particularly in the area of copper and copper alloys. Mr. Fox (shown on the right, with Mr. Moredock) graduated from Lehigh University in 1954 and, following a two-year tour of duty with the Armed Forces, returned to the ma-

terials laboratories at Westinghouse where he specializes in the application of nonferrous metals and alloys. Both authors are A.S.M. members, and Mr. Fox is on the publicity committee of the Pittsburgh Chapter.

The first of two articles in this issue on a new concept of heating – the fluid bed – is by two development engineers at General Electric's industrial heating department in Shelbyville, Ind. – John Stauffer and C. O. Pedersen, shown in the photo below, left to right. (The fluid furnace evolved from work conducted at G.E.) Dr. Stauffer studied chemical engineering at the University of Illinois, then went on to graduate work at Northwestern where his doctoral thesis (in 1955) concerned the physical characteristics of fluid beds. He was a process engineer in the industrial heating department until called to active duty in the air force. Since 1958 he has been chemical process development specialist at G.E.,

working on heat and mass transfer phenomenon in fluid beds and enameling ovens. Mr. Pedersen joined G.E.'s engineering program after receiving his M.S. degree in mechanical engineering from the University of Minnesota in 1958. (He received his B.S. from South Dakota State College two years earlier.) In 1959 he was assigned to the industrial heating department as thermal stress and heat transfer specialist, working on projects for fluid beds and industrial furnaces.

Successful applications of the fluid bed, which is rapidly gaining production status at Boeing Airplane Co., are given by Charles Bennett and Charles Jung, both in the heat treatment group of Boeing's manufacturing development section. The two authors are shown in the photograph on p. 82. (Mr. Bennett is on the right, Mr. Jung on the left.) Mr. Jung majored in metallurgical engineering at Rensselaer Polytechnic Institute, and his industrial background includes four years in the physical research laboratory of Bendix Aviation. He has been with Boeing for four years as a technical specialist, designing and developing heat treatment equipment. Mr. Bennett studied chemical engineering at the University of Washington and has been with Boeing for 5½ years, where he is now lead engineer in the heat treat group.

The latest word from Boeing on the fluid bed (received just before this issue went to press) is that Turnkey Engineering Co., a subsidiary of the Electric Furnace Co., under contract with Boeing, will produce and market the fluid-bed furnace in this country.

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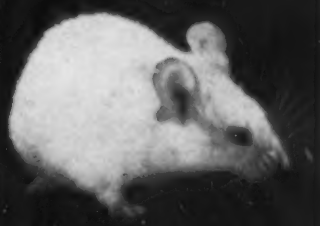

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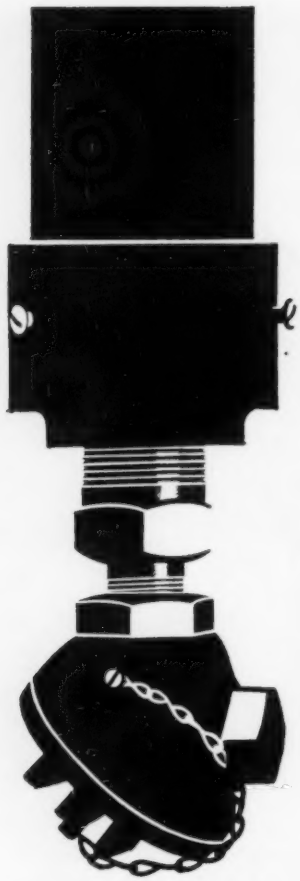

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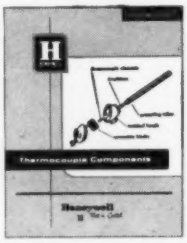

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Circle 1585 on Page 48-B

Louis B. Strader (right), co-author of the article on magnetic-particle testing, which is the second in our series on Nondestructive Testing for Management, has spent more than 18 years in the nondestructive testing field, working with all types of equipment and techniques. He was supervisor of nondestructive testing at Westinghouse's aviation gas turbine division in Kansas City, Mo., until the first of the year when he joined General Electric's missile and space vehicle department in Philadelphia as a specialist in nondestructive testing.

Mr. Collins (left) received a B.S. degree in electrical engineering from Ohio University and began his career at Westinghouse in the graduate student course in 1946. He was assigned to quality control in 1951 and since 1957 has been working on nondestructive testing, most recently as quality control supervisor in the large rotating apparatus department.

C. G. Bieber and T. E. Kihlgren, who present some data on IN-100 – a new nickel-base alloy – on p. 97 are both metallurgists for the International Nickel Co., although in different divisions. Mr. Bieber (below) is head of the special alloys section at Inco's Bayonne, N.J., laboratories where, since 1954, he has worked on such alloys as 713 C. He graduated from the University of Wisconsin, then joined Inco's Huntington, W. Va., works in 1924 where he worked for 15 years as works metallurgist. He has been named lecturer for the 28th annual Sauveur Lecture for the Philadelphia Chapter. Mr. Kihlgren joined Inco in 1927 as a research metallurgist in Bayonne after finishing his studies at Yale (B.S., 1925; M.S., 1927). His responsibilities included directing welding research on nickel-base alloys. For the

past several years he has been in the development and research division in New York, most recently as supervisor of product development in high nickel and superalloys.

Advantages and applications of phosphating in cold solutions are given by Robert C. Gibson on p. 100 – the seventh in our Series on Better Finishing. Dr. Gibson has been a professor of chemistry at Adrian College in Adrian, Mich., since 1958, and before that spent 24 years with Parker Rust Proof Co. in Detroit. For ten years he was research director, engaged in research on metal surface conversion coatings; he still acts as technical consultant to Parker. A 1925 graduate of Adrian, he received his M.S. and Ph.D. from the University of Michigan. His other interests, (besides his work) are varied, including travel, classical music (he's a hi-fi enthusiast), gardening and reading.

The Aerospace Manufacturing Forum held during the S.A.E. National Aeronautical Meeting in Los Angeles in October is reported on p. 106 by W. D. Nelson, J. A. Scott and R. H. Gassner, all at Douglas Aircraft Co. in El Segundo, Calif. Mr. Gassner, chief metallurgist, is familiar to our readers as a *Metal Progress* consulting editor. Mr. Nelson, a test engineer in materials and processing engineering department, has been with Douglas for seven years, working on materials testing. A member of the American Society for Tool and Manufacturing Engineers and the Society

of Experimental Stress Analysis, his other interests include psychotherapy and subliminal education. Mr. Scott graduated from Drexel Institute of Technology with a B.S. in metallurgical engineering and gained industrial experience as a metallurgist in the research laboratory of the Budd Co. He is now a metallurgist in materials and process engineering for Douglas. Actively engaged in church work in his community, he enjoys security analysis in his spare time.

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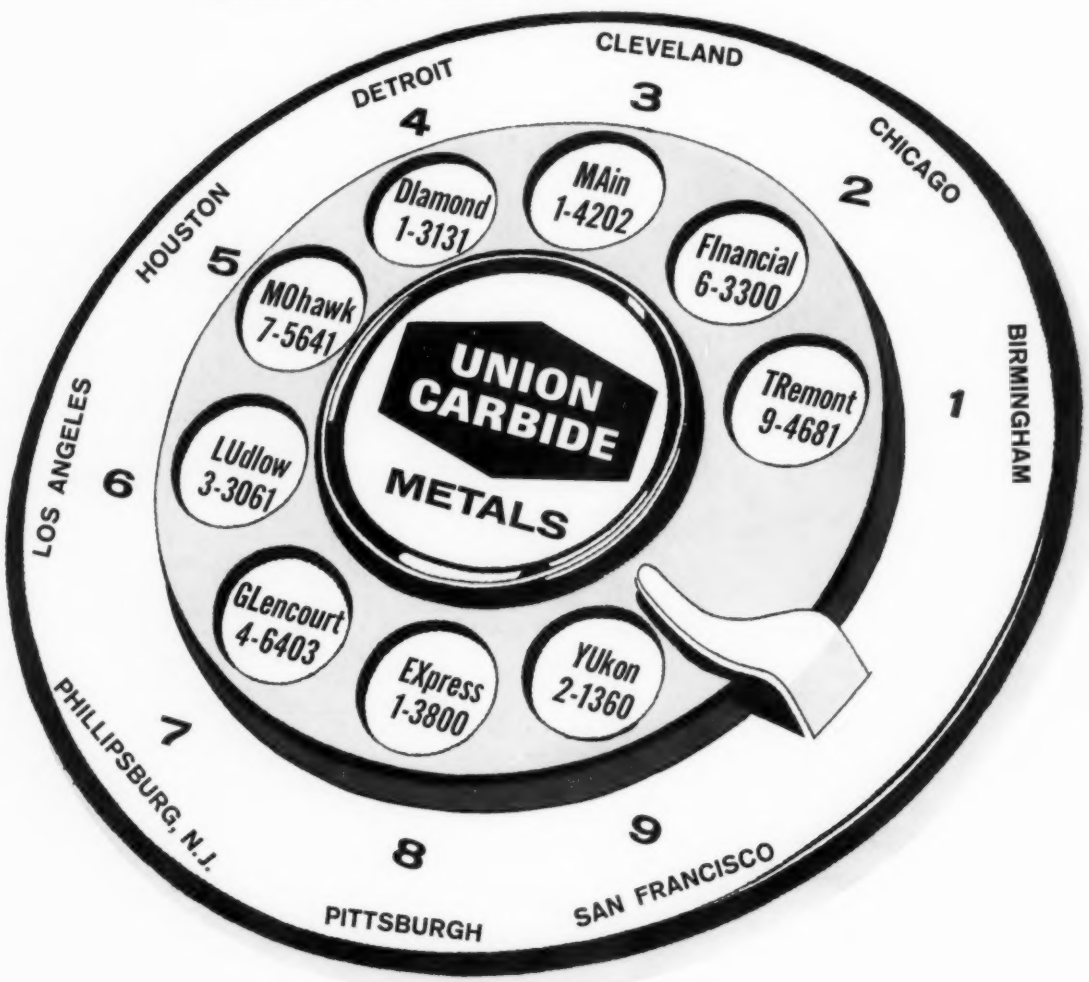

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